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INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

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Devoted to Measurement and Control Problems

Vol. 4. No. 8 Pittsburgh, Pa. August, 1931

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Rapid Inspection Gage
New Automatic Oscillograph
Precision Potentiometer
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Automatic Brake Featured on New Wire Meter
Pulsation Shock Absorber
Directional Gyro
Direct Reading Time Meter
New Indicator Scale Speeds Packing
New Light Sensitive Cell
New Micrometer Microscope
New Steam Trap
Micrometer Water Level and Pressure Gage
New Recording Demand Watthour Meter
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Rubber Conveyors are Synchronized by Thyratron Tubes
New Thermal Converter
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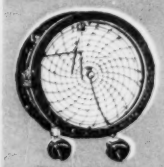

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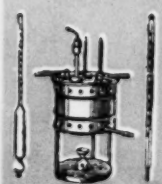

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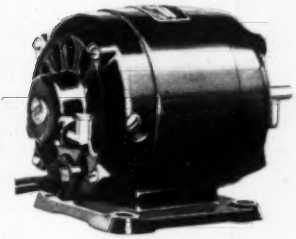

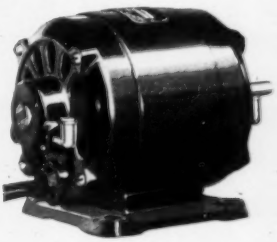

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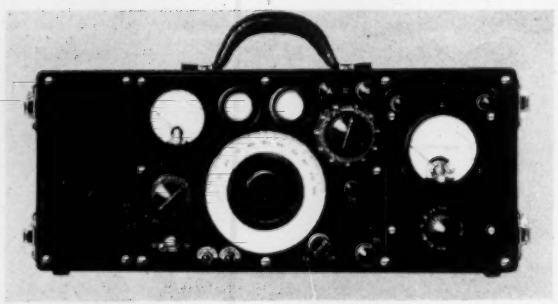

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FEATURES OF MODEL 590

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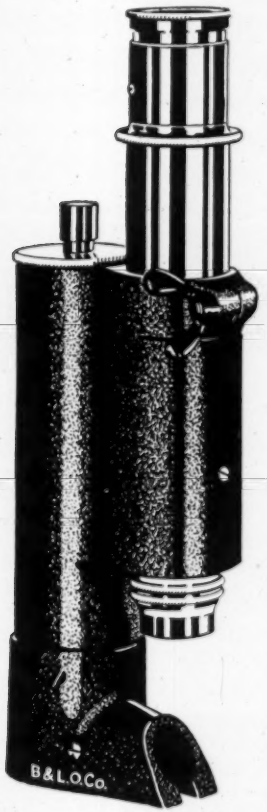

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Richard Rimbach, Managing Editor **M. F. Béhar**, Engineering Editor

Published the 15th of each month by

INSTRUMENTS PUBLISHING COMPANY
3619 FORBES STREET, PITTSBURGH, PA.

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EDITORIAL COMMENT

Reader Cooperation

FROM the establishment of this magazine three and a half years ago to the present day, we have been told that its advertising pages are of practical interest to our readers no less than are the articles, announcements of new instruments, current literature abstracts and book reviews.

A striking proof of this was afforded by the fact that one of the advertisements in the June issue "drew" no less than sixty-six inquiries and two orders.

But here is the interesting part: It appears that fifteen of the letters did *not* mention the advertisement. They could not have been traced to this particular advertisement but for certain precautions that were taken by the advertiser—as a result of which it was absolutely certain that these fifteen inquirers had been impelled to write by reason of their reading the advertisement in the June issue of INSTRUMENTS.

Fifteen out of sixty-six. Nearly one-fourth. Does this mean that one-fourth of *all* our readers fail to do that which has become a customary courtesy comparable to writing "Dear Sir" and "Yours very truly"?

Not so: Ten out of the fifteen are exceptional readers of INSTRUMENTS. They are instrument manufacturers themselves! Some of them make instruments exclusively; others as a side-line.

Among the fifty-one readers who wrote "I saw your ad in INSTRUMENTS" not one appears to be an instrument manufacturer. The proportion of "general" prospective users of the advertised instrument who forgot to write this, therefore, is five out of fifty-six, or about one-tenth. The proportion of instrument-making prospective users who did not write where they saw the advertisement is ten out of ten.

This is probably a coincidence, but it is believed that readers will in the long run benefit themselves by always mentioning "where they saw it" in sending inquiries or orders to companies whose products are advertised or described in INSTRUMENTS.

The editor below quotes from the editorial in the June 1928 issue of INSTRUMENTS:

> The editor takes this opportunity to again point out the necessity for readers mentioning INSTRUMENTS in their dealings with instrument companies. Two cases came to the attention of the editor within a week, in which orders for instruments had been placed with advertisers in INSTRUMENTS but no mention was made on the order or otherwise that the information had been obtained through this journal. Soon after, one of these advertisers cancelled his contract, stating that he had not received the return from his advertising he expected.
>
> It is sad that there must be a commercial side to all efforts of this nature. The instrument companies also must continually keep the commercial side before them; for while they are performing a labor of love, they cannot operate at a loss. A very considerable amount of money is invested by them each year in advertising and this investment must show returns. The value of a publication to the advertiser is estimated by the number of inquiries and orders they receive as a result of their sales messages in that publication.
>
> In approaching instrument companies for further information on anything you see in this journal, kindly mention INSTRUMENTS. You will be performing a service to the manufacturer as well as to INSTRUMENTS.

Your cooperation in always mentioning the source of your information will be appreciated by the advertisers and publishers.

INSTRUMENTS EMPLOYMENT SERVICE

No charge for insertion of notices, which should be addressed to *Instruments* Employment Service, 3619 Forbes Street, Pittsburgh, Pa., should be written tersely and must be received by the 25th of the month. In replying, put identification number on *both* envelope and letter.

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INSTRUMENT MAKER: 7 years experimental laboratory of electrical company. J-1.

INSTRUMENT MAKER: 3½ years experimental laboratory of lamp company; 2 years experimental laboratory of electrical company. J-2.

PYROMETER MAN: Graduate Pennsylvania State College. Had charge of pyrometer calibration laboratory in plant with 1100 pyrometers. J-3.

METALLURGIST: 1½ years University of Pennsylvania; 7 years night school Carnegie Institute of Technology. 2 years steel plant analyst; 7½ years plant metallurgist in foundry. Can read German, Polish, Bohemian and Russian. J-4.

METALLURGIST: Graduate University of Pittsburgh; 5 years steel plant metallurgist; 6 years sales metallurgist; 3 years metallurgist automotive plant. J-5.

ELECTRICAL ENGINEER: Graduate Charlottenburg Technische Hochschule; 8 years research engineer with chemical company; 4 years steel plant electrical engineer; can read German, French, Spanish and Italian. J-6.

METALLURGICAL ENGINEER: Graduate University of Cincinnati, M. S. Carnegie Institute of Technology; research metallurgist steel plant 4 years; development engineer instrument company 1½ years. J-7.

INSTRUMENT SALESMAN: Mechanical Engineering Graduate; experienced sales and service most type of power plant instruments. District Sales Manager 5 years. Experience on gages, flow meter, CO_2 recorders, pyrometers and other testing equipment. J-8.

PYROMETER MAN: 8 years experience; expert electrician and gage (hydraulic, pressure, vacuum, etc.) service man; 3 years instrument laboratory; education equivalent two years of engineering college. J-9.

INSTRUMENT ENGINEER: Graduate Engineering College. Charge of instrument department in large industrial plant for 2½ years. J-10.

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by the Instruments Publishing Company.

PROPERTIES AND MECHANICS OF MATERIALS. By *P. G. Laurson & W. J. Cox.* Wiley & Sons, New York, 1931. Cloth, 6 x 9 inches, 353 pages. Price $3.50.

This is an elementary text book for sophomore students, and not a reference book. It refers to mechanical testing only enough to let the student understand what the data from a tensile test refer to. Fatigue and impact testing are passed over with scarcely more than the mention that they exist.

The description of the properties of metallic materials of engineering is decidedly elementary. From the pedagogic point of view the relative emphasis is probably about right, but readers other than sophomores will not find much they do not already know in the metallurgical part of the book.

The mechanics part is also elementary, but well choosen for its purpose. In reference to building codes, etc., the latest ones are used, and in general the treatment is up to date.

It seems unfortunate that in reference to key-ways on shafting there is no hint that the stress due to the notch is greater than that indicated by the normal formulas. The possibility of failure from local stress, corrosion, fatigue or wear, and the high temperature properties of metals are either not mentioned at all or dismissed with a word.

The book sets out to be a good elementary text book. It is just that and that only.—H. W. Gillett.

THE HANDBOOK OF INDUSTRIAL INSTRUMENTS

CHAPTER XV

Speed and Acceleration

M. F. Béhar*

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3. Counters

Recent years have witnessed the development of many new types of industrial counters, *all* of which can be said to be related to speed in that they are used, or can be used, to measure rate of production, rate of flow, etc. However, since we are dealing here only with the measurement of the speed of machinery, this Section will be limited to revolution and stroke counters, special-purpose industrial counters being described in various other appropriate chapters. Stroke counters are modifications of revolution counters, so that only these latter need be illustrated and described in detail.

(a) Absolute Accuracy Essential

The "measurement" of number of revolutions or strokes should be and generally can be an exact determination. There never need be any question as to the "degree of accuracy" of the measurement. In the first place, if a counter is not *absolutely* accurate when positively driven and when properly used at a reasonable rate, it is utterly unsuitable for speed measurement. Most manufacturers of counters recognize this and designate as "speed" counters or specifically as revolution counters those instruments which are suitable for speed measurement, and the catalogs generally specify a maximum speed beyond which absolute accuracy is not guaranteed. These counters are inherently "perfectly" accurate. Other counters on the market, however, while often of similar outward appearance, are subject to errors—as can be proved by the fact that two or more of these cheap

*Engineering Editor

devices will not agree in their increments after being driven positively and simultaneously for a few minutes. "Coasting of numbers" is the usual name of the commonest defect of counters not designed for engineering purposes.

In the second place, a "perfect" counter should—and can—so be used that it will unquestionably register the exact count. Inaccuracy (or at least uncertainty) results from three things:

One is reliance on friction. Fig. 511 shows a form of positive drive which can readily be adapted or modified to suit individual requirements. No matter how little force it takes to make even a small and practically frictionless counter register, the form of drive should be such that its readings are unquestionable.

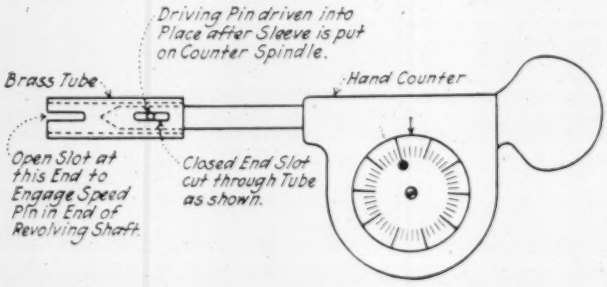

Driving Pin driven into Place after Sleeve is put on Counter Spindle.
Brass Tube
Hand Counter
Open Slot at this End to Engage Speed Pin in End of Revolving Shaft
Closed End Slot cut through Tube as shown.

Fig. 511

Another cause of inaccuracy in measuring r.p.m. with a counter is inaccuracy of the timepiece. Good stop-watches are so inexpensive that no more need be said.

The third cause of inaccuracy, even with a positively driven "perfect" counter and with a high-grade stop-watch, is the starting and stopping error. This error can in turn be split up into three components: (1) lack of synchronism in operating counter and stop-watch on starting; (2) ditto on stopping; (3) the scale division error, i.e., the fact that the usual stop-watch can only be read to a fifth of a second. The obvious way to make the starting and stopping error vanishingly small is to take readings over long periods. In addition, it is well for every operator not only to get used to the same counter and the same stop-watch but to follow always the same correct or nearly correct procedure, because a certain amount of skill is required in using most hand counters and in reading some continuous counters.

(*End-thrust error*—It is not amiss to mention again that pressing the spindle of an instrument against the end of a rotating shaft may slow down light machinery. This error, however, is not solely inherent in the counter and timepiece method.)

(b) Characteristics

Counters make it possible to measure *average* speed with practically perfect accuracy, but only when positively driven. They are reliable, simple in construction, trouble-free and comparatively inexpensive. Continuous or stationary models can be driven by flexible shafts of considerable length but this introduces an error of generally unknown magnitude at each reversal of rotation. Electromagnetic remote drives are practicable both for stroke counters and for revolution counters. All counters can be used for slow speeds and some can be used for speeds up to 10,000 r.p.m. Ac-

curacy of registration is not affected by speed or by external conditions such as temperature, magnetic fields, vibrations, atmospheric humidity and dust, etc. Counters cannot indicate ordinary speed fluctuations, cannot measure instantaneous speed and cannot measure speed except in connection with measurement of time period. Little skill is required but close attention is imperative.

(c) Hand Counters

There are two well-known forms of hand counters and each is a distinct type, having characteristics not possessed by the other.

Geared Type—This is the familiar type in which a dial is rotated by a worm on the spindle. Fig. 512 shows the well-known "No. 107" of the L. J. Starrett Mfg. Co., which is a comparatively recent design with two

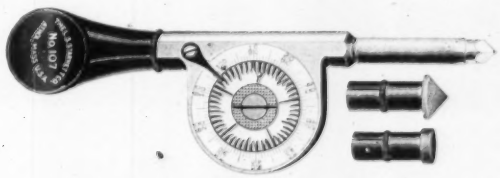


Fig. 512

dials and other features such as a hard-rubber handle making it safe to use on electrical machinery. This instrument will register 5000 revolutions and repeat. The large dial is graduated into 100 lines, each one representing a revolution of the spindle. The small dial has 50 lines cut upon its face, each representing 100 revolutions of the spindle (or one complete turn of the large dial.) A spring finger trip attached to the case engages with one of the lines in the small dial and holds it from revolving until the large dial makes one complete turn, when the trip pin passing under the spring trip lifts it, and the dial is frictionally carried along by the large plate one line, thus showing that 100 revolutions of the spindle have been made.

Among the various models of this type of revolution counter on the market are some in which the dials are friction-driven so that they may be set at zero before taking readings and held at zero (prevented from rotating while the spindle is rotating) until the second hand of an ordinary watch gets to the right position to take starting time. This feature is described as "an improvement" but it is that for rough work only, as it introduces an element of uncertainty not to be tolerated in engineering measurements.

Why manufacturers persist in calling these instruments "Speed Indicators" in their catalogs is a mystery. Counters do not measure speed; and they are registering—not indicating—instruments.

Cyclometer Type—As hinted above, many models of this type are not suitable for speed measurement work, but there are numerous suitable models on the market. Fig. 513 shows, in its actual size, the "clutch" revolution counter made by Veeder-Root Incorporated. It is so designated because the spindle will rotate without driving the register until the counter is pressed against the end of the shaft: "The tip of the counter is placed lightly at exact center of the revolving shaft. The spindle will then turn freely, without engaging the recording mechanism. By slightly pressing the counter against the shaft, a clutch is engaged, which instantly starts the

recording mechanism. This is done when the second hand of the watch comes to any convenient point on the dial. At the end of the minute . . . the pressure on the counter is released; the clutch disengages; the counting stops instantly. The number recorded on the dial is the exact number of revolutions per minute . . . made by the part being timed."

The direct-reading feature of a cyclometer index is always a convenience, and the clutch feature reduces starting and stopping errors when no stop-watch is available, in that the operator's attention can be given to the second hand of an ordinary watch. On the other hand, in the non-reset models it is necessary to take two readings and subtract the lower from the higher to get the count—which introduces the possibility of personal errors.

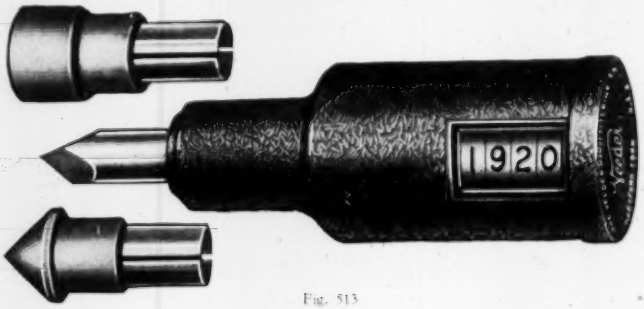


Fig. 513

(d) Continuous Counters

Designed for permanent installation, these counters are generally built for industrial service and include large and rugged models of absolute reliability. Readings may be taken over time periods of any desired length, so that average speed may be measured with perfect accuracy.

Continuous counters may be divided into those operated by oscillating levers and those operated by rotating shafts. The former are usually called stroke counters and the latter revolution counters but a lever connection may be used to count revolutions, and vice versa. We can forget this distinction and divide them into types corresponding to those of the hand counters, namely (1) direct-geared and (2) cyclometer, adding (3) flat ratchet, a type in which—to the author's knowledge—hand counters are not made up.

Direct-Geared—Counters of this type are only driven by rotation—not by an oscillating member. They simply consist of a set of gears to which rotating dials (or rotating pointers traveling on fixed dials) are *positively* connected. Friction drives of dials or pointers should not be tolerated, since the convenience of quick and easy zero setting is seldom desired in most industrial installations, and since there are available set-back devices which do not affect positiveness of registration. The same remark applies of course to driction drives of the counters.

Cyclometer—Counters of this type are characterized by the direct-reading cyclometer index which distinguishes them at a glance. Apart from a great variety of sizes and forms, there are important differences in the mechanical operation of various models, so that a further division would seem to be needed, into *types of mechanisms*. The most important of these types are named and described by Veeder-Root Inc., as follows:

A *Revolution Counter* adds one for each complete revolution of the shaft in one direction. The *Non-Reset* Revolution Counter subtracts one for each complete revolution of the shaft in the reverse direction. The *Reset* Revolution Counter generally subtracts when the shaft is turned reversely but this we do not guarantee. It is not recommended that the Non-Reset Revolution Counter be operated at speeds exceeding 1,000 counts per minute. It is not recommended that the Reset Revolution Counter be operated at speeds exceeding 500 counts per minute, although for short periods it may be as high as 1,000 counts per minute.

A *Star Revolution Counter* adds one for each one-fifth of a revolution of the star wheel or when the star wheel is rotated a distance equal to the space between two of its points. It registers five for one complete revolution of the star wheel. When run backward, this counter will subtract.

A *Direct Drive Counter* adds one for each one-tenth revoltuion of the shaft in one direction (adding 10 for a complete revolution). The *Non-Reset* Direct Drive Counter subtracts one

Fig. 514

for each one-tenth revolution of the shaft in the reverse direction (subtracting 10 for a complete revolution). The *Reset* Direct Drive Counter generally subtracts when the shaft is turned reversely but this we do not guarantee. It is not recommended that the Non-Reset Drive Counter be operated at speeds exceeding 800 counts per minute. It is not recommended that the Reset Direct Drive Counter be operated at speeds exceeding 400 counts per minute, although for short periods it may be run somewhat faster than this.

A *Rotary Ratchet Counter* adds 10 for each complete revolution or one for one-tenth of a revolution of the shaft in one direction. It adds one for each oscillation of the shaft through an angle of from 40 to 60 degrees. When the shaft is turned backward, or oscillated through an angle of less than 36 degrees, the figures remain stationary. It is not recommended that the Non-Reset Rotary Ratchet Counter be operated at speeds exceeding 300 counts per minute, although for short periods it may be run somewhat higher than this. It is not recommended that the Reset Rotary Ratchet Counter be operated at speeds exceeding 150 counts per minute, although for short periods it may be run as high as 300 counts per minute.

A *Ratchet Counter with Stops* has the movement of the shaft limited to 45 degrees. It adds one for each oscillation of the shaft through an angle of from 40 to 45 degrees. When the shaft is ocillated through an angle of less than 36 degrees, the figures remain stationary.

The foregoing detailed (and frank) statements set forth the different *general* characteristics of the various sub-types of continuous cyclometer counters. They do not apply to all such instrument, as a careful examination of the catalogs of several different manufacturers discloses a few exceptions. As a rule, though, the "revolution counter non-reset" or locked-wheel sub-type of continuous cyclometer counter is seen to be preferable for higher speeds; and the set-back feature is seen to be undesirable in cyclometer counters to be installed where direction is reversed.

Since direction is not reversed in the majority of industrial installations, set-back cyclometer counters are frequently specified. Fig. 514 (The Bristol Co.) shows a typical industrial counter of the continuous cyclometer type, revolution counter sub-type with set-back feature. The black enameled all-metal case enclosing the working parts is "absolutely dust- and moisture-proof."

Flat Ratchet Type—This is the oldest and most familiar type, seen on most makes of presses, etc. Mostly made up for machinery manufacturers. Widely used for production counting. Seldom used as instruments for speed measurement. Each model has limited characteristics. The operation is by reciprocating motion which must be rather carefully adjusted on each installation, to prevent non-registration at one extreme and "coasting" at the other.

4. Combined Tachoscopes

This class of instruments is the obvious response to a logical demand arising in connection with the counter and timepiece method of measuring speed. It not only combines into one convenient speed measuring instrument the counter and the timepiece which otherwise would be unrelated except when in use, but it is as a rule (in the models on the market) the result of a search for a suitable counter and a suitable stop-watch . . . a point worth considering.

In addition to the reasonable assurance that a tachoscope comprises a selected counter and a selected stop-watch, there is the absolute assurance of minimized starting and stopping error—by reason of an arrangement for simultaneously starting and stopping the counter and the watch.

Outside of this arrangement there are no features, common to all instruments of this class, to which attention need be called. Each make or model has its own features. Nor is there any practical need for classifying tachoscopes into types: there are too few distinct types on the market.

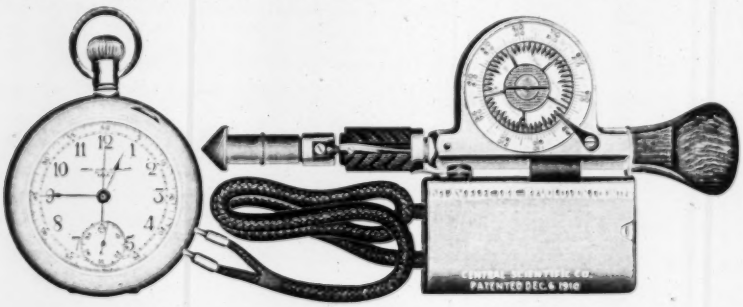


Fig. 515

Characteristics simply are those of the method involved. Great accuracy when the stop-watch is well regulated, when the drive is positive so that the spindle cannot slip, and when readings are prolonged so that the scale division error (usually $\frac{1}{5}$ second) will be minimized. Average speed is obtained; instantaneous speed cannot be read; speed fluctuations cannot be indicated. Reading remains until the operator sets the counter and the watch back to zero. Energy consumption is negligible so that light machinery is not slowed down (except for possible end-thrust effect of shaft-end contact drives). Tachoscopes can be used as Plant Standards for calibration purposes where a constant speed device is available.

Fig. 515 (Central Scientific Co.) shows a form of tachoscope in which the synchronization of counter and stop-watch is electrical. The counter is of the geared type which may be used for either direction of rotation, and is equipped with a contact device. An ordinary flashlight battery furnishes the requisite current. To use the device, the circuit is first closed. Placing the counter spindle tip against the center of the revolving shaft closes the

circuit and stops the hand. Pressing the stem of the watch holds the hand mechanically so that the circuit may be opened.

Fig. 516 (Gaertner Scientific Corp.) shows a recently brought out tachoscope called the "Probator" which combines with a stop watch a cyclometer type of counter that works in both directions and is said to be suitable for

DIAL SHOWING NUMBER OF REVOLUTIONS
RESETS AND WINDS WATCH
NUMBER OF SECONDS ELAPSED
0672
RESET DIALS TO 0000 WITH ONE TURN
SPINDLE TO BE PRESSED AGAINST END OF REVOLVING OBJECT

Fig. 516

speeds up to 6000 r.p.m. As the legends in Fig. 516 indicate, the counter and watch start simultaneously when the spindle is pressed and stop simultaneously when pressure is released.

Fig. 517 shows the form of tachoscope which is probably the most widespread, being made in several models closely resembling one another. The particular tachoscope illustrated (Herman H. Stitcht & Co.) is said to be suitable for speeds up to 30,000 r.p.m. Tachoscopes of this form may be pressed against the end of a revolving shaft and their spindles will idle until a button or trigger (X in the illustration) is pressed forward by the thumb, when counter and watch start simultaneously, stopping simultaneously when this same trigger is pressed a second time. The readings remain on counter and watch until they are set back to zero by pressing small levers provided for that purpose. The counter has three pointers: The large pointer travels over a scale graduated 0-100 revolutions in intervals of one revolution. The small pointer at the right travels over a scale graduated 0-1000 revolutions in intervals of 100 revolutions. The small pointer at the left travels over a scale graduated 0-10,000 revolutions in intervals of 1000 revolutions.

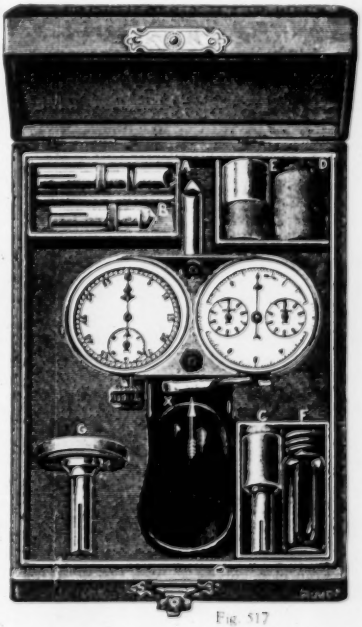


Fig. 517

In a letter dated June 12, 1931, Mr. H. H. Sticht writes: "The Tachoscope is the standard for speed measurements in the large trans-oceanic radio stations that have the Alexanderson 1200-pole generators. Since the variation between wave lengths for these stations is very small, it is necessary to have the frequency, which means the generator's speed, as accurate as it is humanly possible. In these stations it is the practice to use the tachoscope daily. Readings are taken for a period of 20 minutes or 1200 seconds. With the starting and stopping error of the stop watch of the order of 0.1 second this means that they are measuring the speed with an accuracy of one part in 12,000 or approximately *one-hundredth of one percent*. This method is, of course, made possible by the very fine system of speed control that assures an absolute constant speed during the 20 minutes."

5. "Speed Indicators"

If a combined tachoscope, say of the type shown in Fig. 517, were provided with an automatic timer whereby each reading would cover a period of exactly one minute, the stop-watch *dial* would not be needed since the counter dial would directly indicate the revolutions, *i.e.* the average speed for the one-minute period. The timepiece movement would of course be needed for the purpose of timing.

If the automatic timing were for a six-second period, the counter reading would have to be multiplied by 10 to give r.p.m.—or the counter dial could simply be so scaled that the reading would be ten times the number of revolutions effecting movement of the pointer during the six seconds.

If the automatic timing were for three seconds, the multiplying factor would be twenty.

This is exactly the principle of the class of instruments now considered—the "Speed Indicators." One of these was illustrated in Section I (Fig.

Fig. 518

501). The "Hasler" instrument (Hasler Tel. Co., U. S. agents, Société Anonyme Hasler, Switzerland) is described as follows:

The mechanism, shown in Figs. 518 and 519, is a combination of two units: (1) A revolution counter made up of a spindle driving a measuring wheel through bevel gears and an indicating hand traveling on a dial; (2) A chronometric movement, balance wheel, escapement, etc.

The synchronization of these two units is done by means of a cam mounted on the escapement wheel and a ratchet. When the spindle is revolved, the ratchet, controlled by the chronometric movement, frees the measuring wheel for a definite period of time. The motion of the measuring wheel is proportional to the speed of the spindle. At the end of the timing period, the ratchet locks the measuring wheel with the result that its travel per unit of time is: (Number of teeth)/(Timing period), and the indicating hand mounted on the measuring wheel translates this result directly into the quotient: Speed.

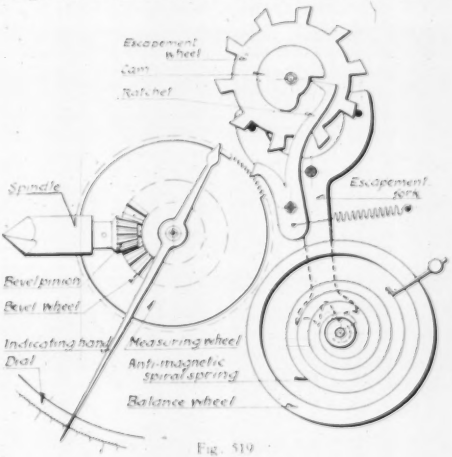


Fig. 519

The mechanism as actually constructed is made up of the two units described above. These units are synchronized and so combined as to form the complete mechanism. Due to this synchronization the operation of the instrument is entirely automatic. The chronometric movement has the regular balance wheel B, antimagnetic spiral spring E and escapement F. This movement operates intermittently by means of button B. When the button is pressed, it winds the main spring; when the button is released, the spring unwinds, furnishing the necessary power to the balance wheel. The movement operates during 5 seconds only and in three periods as follows:

1st Period—One second to obtain regularity of oscillation.

2nd Period—Exactly three seconds to secure the measurement.

3rd Period—One second to allow the balance wheel to stop.

The timing adjustment is said to be made within 1/1000 of a second.

Precisely at the beginning of the 2nd second, a cam G, mounted on the escapement, lifts the ratchet H, releasing the registering wheel J of the counter, and permits the hands to move until the end of the 4th second, at which precise time the cam places the ratchet in a locking position on the registering wheel.

The geared revolution counter is an assembly of a spindle A, a set of finely cut bevels L, and a series of spur gears, a system of gears to automatically reverse the anticlockwise rotation of spindle, a registering wheel J bearing the large hand, a gear set M of the small hand and a resetting system to zero K, operated by the button C. The registering wheel is the part of the counter on which the accuracy depends. It is a 200-tooth wheel, of 27/32″ diameter, which is released or locked by the timing ratchet. The complete mechanism is contained in an aluminum case.

Operation—The instrument is held in the palm of the hand, the tip is brought in contact with the shaft, parallel to its axis, and held in position by gentle pressure. The spindle of the instrument starts to rotate and reaches, almost immediately, the speed of the machine shaft, but this spindle runs freely without operating the registering mechanism, until the button B, pressed and released, starts the chronometric movement.

One second after the button B is released, the timing ratchet unlocks the registering wheel of the counter, and both large and small hands start to move on the dial until the timing ratchet locks the registering wheel and stops the hands. The instrument is moved away from the shaft, the hands remain in position as long as desired, and the speed indicated may be read at leisure.

There are two rows of figures on the dial (see Fig. 520). The outer figures are black, the inner figures red. The black figures show r.p.m. The speed indicated by the instrument shown in Fig. 520 would be as follows:

Small hand, One division (outer circle)	1,000
Large hand, (outer circle)	232
Speed	1,232 r.p.m.

After the reading, the hands are set back to zero by pressing the button C and the instrument is ready for another test.

Mean Speed in r.p.m.—Two or more consecutive tests, without setting back the hands at zero, give the speed sum of the number of tests. In the case illustrated above, the speed was 1,232 r.p.m., but had the button B been pressed and released again after the hands had come to a full stop, the reading obtained would have been 2,464 r.p.m. or the sum of the two tests, provided the motor speed was constant. The mean speed would be 1,232 r.p.m.

The red figures show linear or circumferential speeds. For the speed of a pulley, for instance, the disk attachment is used. In this case the red figures are read instead of the black. Should the hands be in the position shown in Fig. 520, the speed would be:

Small hand, One division (inner circle)	300
Large hand, (inner circle)	70
Speed of Pulley	370 F.p.m.

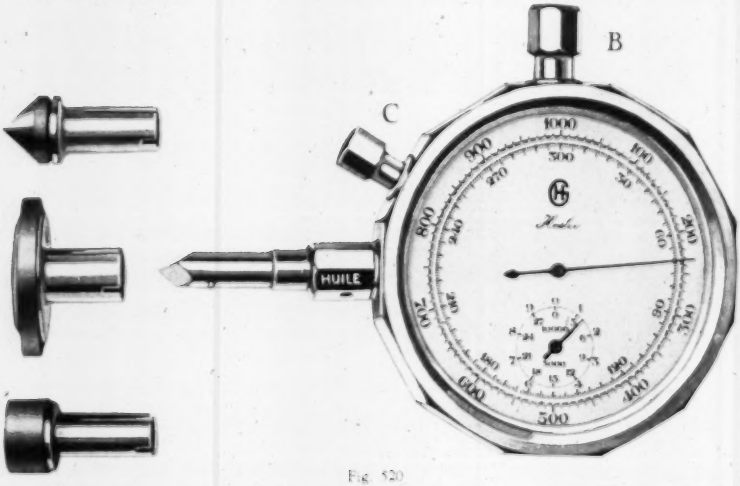


Fig. 520

Characteristics—The above description of the Hasler instrument is generally applicable to all other speed indicators, except that in some other instruments the measuring period is six seconds and the time required for each test is ten seconds. Speed indicators are deservedly growing in popularity. They are almost "vest pocket" instruments. The error is usually

well within 1% and by "adding the speeds" of several readings as described above, the accuracy of measurement of average speed is increased. The scale is uniform, but in spite of the fact that starting and stopping error and scale error are very small, speed indicators should preferably be used in the upper part of their scale ranges. This is a distinct limitation. However, since these instruments are comparatively inexpensive, many users order them in sets of two: one instrument with a dial reading up to, say, 1000 r.p.m. and 300 F.p.m., and the other with a dial reading up to 10,000 r.p.m. or 3000 F.p.m. Speed indicators require no more care than a fine watch and can be relied upon to stay accurate satisfactorily long, but when they get out of order they must be returned to the manufacturer. Driving torque being negligible, they can be used on light machinery without fear of slowing it except for possible end-thrust effect. Finally, speed indicators can be used as Plant Standards for *checking* other instruments at speeds in the upper part of the scale, *but not for calibrating at all speeds.*

Sections 6 to 19. TACHOMETERS

6. Chronometric Tachometers

In this class the counter and timepiece method of measuring speed is brought to its culmination. The tachoscope (Section 4) simply assembles two instruments and provides a synchronizing connection. The speed indicator (Section 5) combines the two, does away with the timepiece dial, and becomes one compact instrument but it requires manual operation, providing as it does only one reading each time it is operated. The chronometric tachometer employs a principle similar to that of the speed indicator (counting revolutions during a time period) but differs in the important respect that it *repeats automatically*, so that, for instance, the pointer of an indicating instrument does not return to zero but remains in place while the measured speed is constant, periodically moving to a new position on the scale whenever the average speed changes between successive cycles of automatic measuring operation. Chronometric tachometers can therefore be made up for industrial applications into stationary indicating and recording models that resemble other "typical industrial" instruments; also into small light "hand" models and into speedometers for automotive, aeronautical and nautical purposes.

Chronometric tachometers the construction of which follows closely that of the speed indicators may be called integrating; those which successively conjugate actuated members with rotating members may be called conjugating. This is a minor distinction: there are other constructions based on the chronometric principle. In every case the number of revolutions made by the primary shaft is "counted" during a definite period.

One of the oldest chronometric tachometers is the *Van Sicklen* integrating instrument, shown diagramatically in Fig. 521 and described by Diederichs & Andrae substantially as follows:

The essential units are the driving mechanism, the power-plant, commonly a clock spring wound through a friction mechanism by the driving mechanism, a set of synchronizing cams, a watch mechanism, and an indicator or counter mechanism. Drive shaft A, through B and C, winds the

spring in the barrel D, which drives the escapement wheel F'. One end of this spring is loose, so that slipping starts when the tension has reached a certain value, and by this means the driving force is kept always constant. The barrel shaft E carries the watch mechanism FF' and the set of synchronizing cams G with follower H and the pawls I and J. Gears K, L, and M constitute the counter mechanism.

The action is as follows. The watch mechanism allows the cam shaft E to make $\frac{1}{12}$ of a revolution every $\frac{1}{2}$ second. The inner cam through the follower H allows the gear K to mesh with gear L for exactly one second.

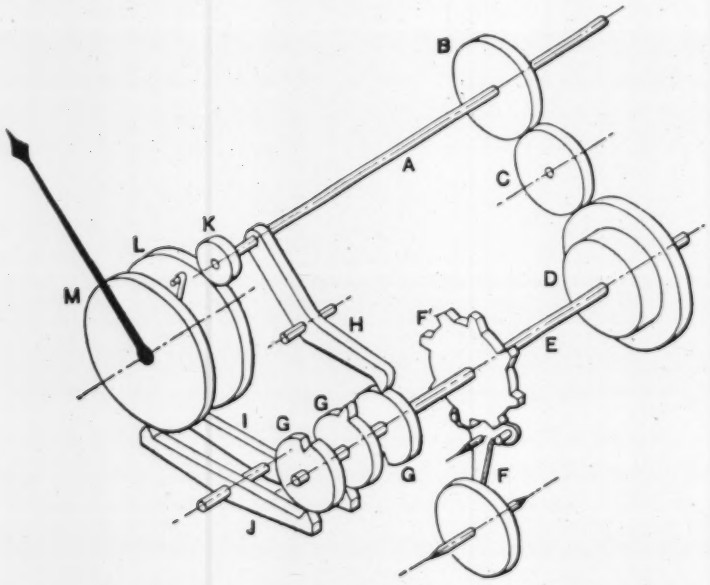


Fig. 521

The angular displacement of L during the second of time is therefore a measure of the speed of rotation of the drive shaft. Gear L is loose on the pointer spindle, but engages gear M and the pointer through a spring arm and carries them through the same angular displacement. At the end of the second, when K disengages L, the latter gear is allowed to return to zero by action of pawl I and the middle cam. In the meantime the outer cam and pawl J lock in position the pointer wheel M. When this series of actions is next repeated, there will be no motion of the pointer if there has been no change in the speed; but if a change has occurred, the pointer wheel will either be carried around farther for an increase or it will be allowed to drop back, if there has been a decrease. Thus the pointer at any time indicates the speed for the previous second as long as the drive shaft is engaged.

The *Hasler* "*Tel*" tachometer (R. W. Cramer & Co.) is of the chronometric conjugating type. The construction of the indicating model for aircraft, etc., is shown schematically in Fig. 522. Three timing sectors M_1, M_2, M_3, envelop a spline shaft W, along which they are free to slide in grooves. The sectors are toothed externally. The gear A at the lower end of the spline shaft is actuated by a chronometric escapement which rotates it through 120 degrees every second. A collar R which encircles the spline

shaft is always resting on that sector which has been raised the highest. By means of a toothed rack attached to R, the movement of this collar is transmitted to the pointer Z.

The raising of the sectors is effected by the measuring pinion O, which turns at a rate proportional to the speed. The more rapidly turns the measuring pinion O, the higher rises the sector then in engagement with the pinion during a time period of exactly one second. The rotation of the spline shaft brings a fresh sector every second into engagement with the pinion O; i.e., every second a new measuring period begins. By means of a

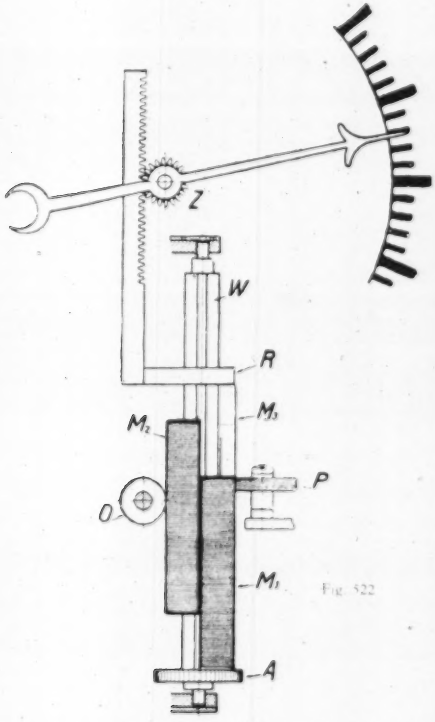


Fig. 522

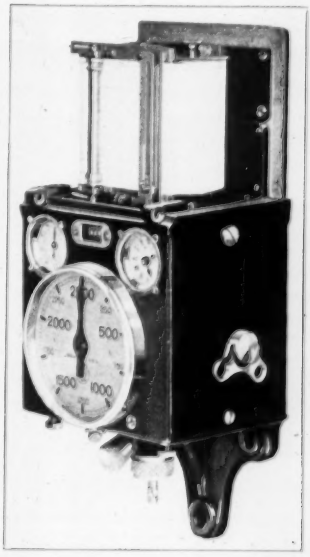


Fig. 523

detention roller P the raised sector is held in its elevated position, thereby holding the pointer steady during the second second. During the third second, the released sector has sufficient time to return to its position of rest in order to begin afresh its operation at the beginning of the fourth second. All three sectors perform this cycle of operations with a successive phase difference of one second. The pointer is thus set anew every second to the mean speed of the last preceding second.

The same conjugating principle is employed in the construction of other "Tel" chronometric instruments. Fig. 523 shows a combination automotive speedometer (with chart cover removed).

Owing to the principle and to construction features not shown in Fig. 522, the accuracy is said to be unaffected by "altitude, momentum, inertia, shocks, gravity, magnetism or sudden changes in temperature." These instruments are not unknown in the U. S., being widely used, but their principle (now set forth above) has been relatively unknown here.

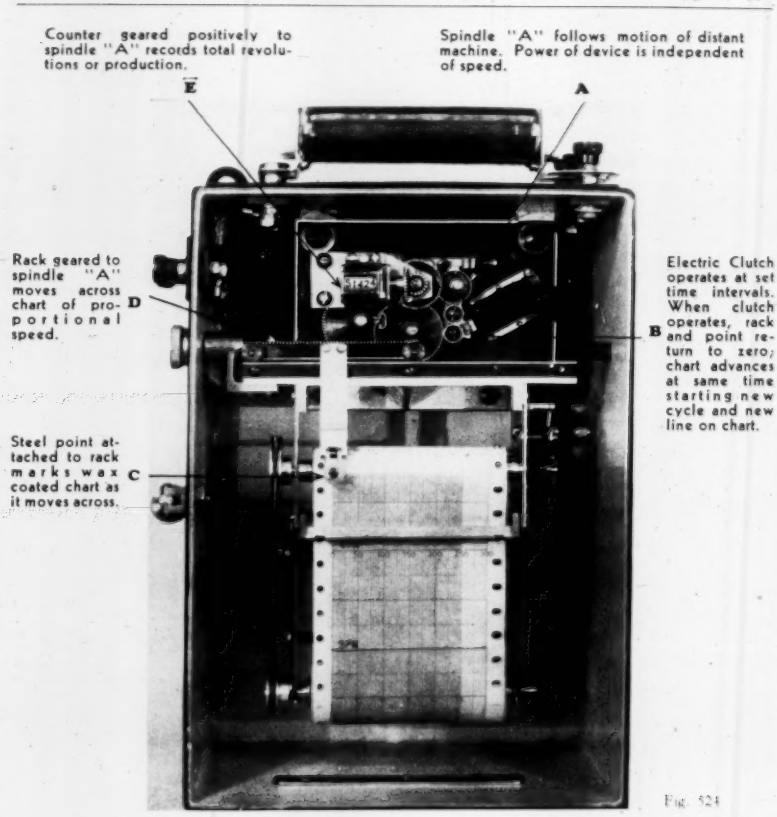

Counter geared positively to spindle "A" records total revolutions or production.
Spindle "A" follows motion of distant machine. Power of device is independent of speed.
E
A
Rack geared to spindle "A" moves across chart of proportional speed.
D
Electric Clutch operates at set time intervals. When clutch operates, rack and point return to zero; chart advances at same time starting new cycle and new line on chart.
B
Steel point attached to rack marks wax coated chart as it moves across.
C

Fig. 524

An interesting and characteristically industrial speed recording integrating instrument is that of the *Electric Tachometer Corporation*. It is the only chronometric recording tachometer made in the U. S. and probably is the only long-distance chronometric recording tachometer made anywhere. The equipment comprises (1) a contactor driven by the machine whose speed is to be recorded, (2) a contact-clock which may be located anywhere, (3) a recorder, such as that shown in Fig. 524, which too may be located where most convenient, (4) a cyclometer counter built into the recording instrument. The following is the substance of the maker's description:

The Master Clock may be located at any distance from the recorder, allowing installation where least liable to mechanical injury and where most convenient for winding. The clock is a high grade jeweled marine movement. It is relieved of the continuous strain of moving the chart. *Any number of recorders may be operated from the same clock, insuring uniform accuracy and synchronous records.*

Operation: A three-point contactor is driven from a revolving shaft by means of gears or pulleys and belt. The speed ratio is so arranged that the contactor runs at 200 r.p.m. for full scale reading on the chart. The contactor is connected to the recording instrument by means of a four-conductor cable.

The recording instrument, which can be installed at any convenient location, is connected to a source of direct current, usually 110 volts. It is also connected by means of a two-conductor cable to the contact clock. Resistors are furnished to provide for any voltage of direct current. Fluctuations of 15% plus or minus in the voltage have no effect on the accuracy of the record.

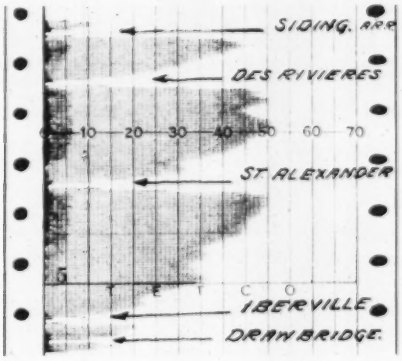


Fig. 525

As the contactor is rotated by the drive shaft, a step-by-step motor in the recorder follows this motion at a proportional speed. This motor is geared to a rack through a tumbler gear. The recorder pen is attached to this rack. As the motor revolves, the rack and pen are moved across the scale. At the end of 27 seconds, the gear is disengaged, allowing the rack and pen to come back to zero. They remain at zero for three seconds, while the chart is advanced. This cycle of operation is repeated every thirty seconds.

The above operation produces on the chart a series of parallel lines spaced at about 1/60 of an inch apart. The ends of these lines form a continuous curve, recording the speed of the drive shaft. This curve is necessarily as accurate as the time-keeping qualities of the clock.

Recorders having an operating cycle of *fifteen*, *twenty* or *sixty* seconds can be furnished.

". . . Recorder R-100 has been designed especially for installation in mills, power plants, etc., where conditions are not always favorable . . . All parts of the recorder run at a very low speed. This feature eliminates the use of speed-up gears . . . The accuracy depends only on the time-keeping qualities of the clock. One half of one per cent is the normal error. The accuracy is not affected by temperature, resistance, vibration or wear of parts . . . The chart feed is fast enough to note stops and fluctuations . . . The record is visible for 4" of its length . . . The record, because of its peculiar nature, can be plainly seen from a considerable distance . . . The complete recorder movement can be taken out of the case by the removal of only two screws. The mechanism may be held in the examiner's hand while running . . . The integrating counter for reading total production is a feature not found in any other recorder. It is useful for checking the accuracy of the record and for counting production during a given time period . . . The counter can be arranged to show total yards of product, miles traveled, gallons pumped, etc., as well as total revolutions."

Fig. 525 shows a portion of a chart from a "Tetco" recorder, being a record of the speed of a steam train, showing station stops and speed changes. The length of each horizontal line is proportional to the number of miles traveled during the preceding time interval. The ends of the lines form a speed curve which is read directly in miles per hour.

Characteristics—All chronometric tachometers have a uniform scale, determined by the ratios and dimensions of mechanical members. The limit of error of high grade commercial instruments is within ½ of one percent of the scale range. The accuracy, as in speed indicators, depends upon the fineness of the teeth on some of the gears, because tooth width at some point determines the instant of engagement. The accuracy is seldom affected by external factors. The wear of parts does not affect accuracy until it becomes serious. Instantaneous speed cannot be measured, but fluctuations of durations decidedly longer than the cycle period of any particular instrument can be observed. Requisite driving torque is negligible. A wide range of speeds can be measured by any one instrument.

Sections 7 to 14—CENTRIFUGAL TACHOMETERS
(7-10—Centrifugal Weight)

7. Fly-ball

This class of tachometers utilizes the flyball governor principle, which does not need to be explained to the readers of this book. It is divided into two types: the gravity-loaded and the spring-loaded.

The gravity type employs a positive method of measurement. Instruments of this type are primary standards in theory; in practice they have to be calibrated by test against standards. The scale formula can be computed in designing any particular instrument, from its geometrical properties, etc., but usually this is only done to determine its range. The scale obtained directly from the elevation of the sliding collar is not uniform. A uniform scale requires suitable linkage and gears between the sliding collar and the pointer pinion, and uniformity is seldom attained over the full

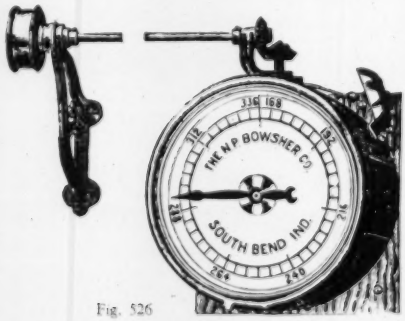


Fig. 526

range from zero speed to practical maximum. (The theoretical maximum is infinite speed, with ball rods at right angle to the main spindle, but it is of no practical interest.) Calibration over the useful range is permanent but is seriously affected in practice by the position of the instrument and slightly affected by lubrication, temperature and wear. Permanence of calibration over the useful range is perhaps the outstanding characteristic of this type, resulting in *reliability*. Instruments of this type have been in continuous service for twenty years and more. Fig. 526 shows a model made with few changes in the last sixty years by the N. P. Bowsher Co.

The spring-loaded type of the true fly-ball class (with vertical main spindle) is neither primary nor positive, but actual tachometers of this type can be made to respond much more rapidly and sensitively to brief variations in

instantaneous speed. A good analogy is the field of pressure-measuring instruments, where dead-weight gages, etc. are primary and Bourdon gages secondary. Accuracy depends not only on position but on the properties of the particular spring employed, as well as on temperature, lubrication, etc.

Whether gravity-loaded or spring-loaded, a flyball tachometer, as actually built, cannot be relied upon to measure accurately either "low" speeds (with the weights hanging close to the shaft, nearly vertically) or "high"

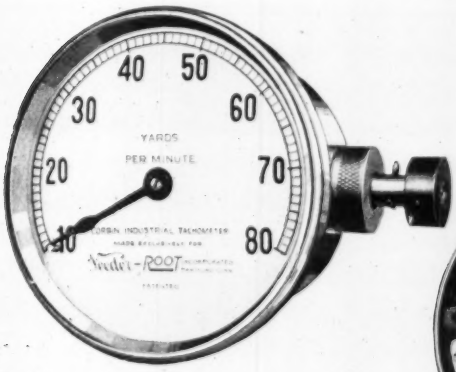
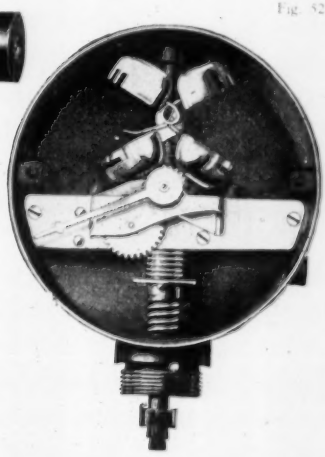


Fig. 527

Fig. 528



speeds (with both weights close to the upper limit of their travel). The reason is that when the first condition prevails the available *force* can hardly overcome friction, and the mechanism "sticks," while at high speeds the available *motion* resulting from changes in speed is vanishingly small. In practice, therefore, fly-ball tachometers are so designed as to take the fullest available advantage of force and motion between these extremes, when the arms are at between 20° and 50° to the vertical shaft. Hence the actual useful scale range is *narrow*, but in this mid-portion the accuracy and sensitivity are usually excellent. Scales usually start at 25 percent of the maximum. Zero cannot be checked. For permanent installation on fairly constant-speed applications, fly-ball tachometers are eminently suitable. Inertia effects preclude their use where there are sudden fluctuations, except when a belt drive is used to deaden these fluctuations.

Figs. 527 and 528 show two Corbin tachometers (Veeder-Root, Inc.) of a modified spring-loaded fly-ball type which is not, however, the cross-pendulum class described in the next section. Fig 527 shows a special industrial form indicating in yards per minute the material passing through a machine. Fig. 528 shows the "Corbin patented counterbalanced weights." This mechanism is said to be so lubricated at the factory as to require no attention.

Horizontal Shaft Form, Remote Reading—An aircraft engine tachometer recently developed in Germany by the Askania Werke (American Askania Corporation, agents) seems to belong in this Section. Fig. 529 shows possibilities of connecting various indicating and recording instruments to the fly-ball transmitter, which possibilities obviously have a wider field than aviation. The principle of the transmitter is shown schematically in Fig. 530 and is explained as follows:

"The working principle underlying our distant-reading . . . is clear from the illustration. An air pressure pipe (we use a small air pump) sends a stream of air through a throttle into a small cylinder, in which is a small easily movable piston. At a certain height there are slits in

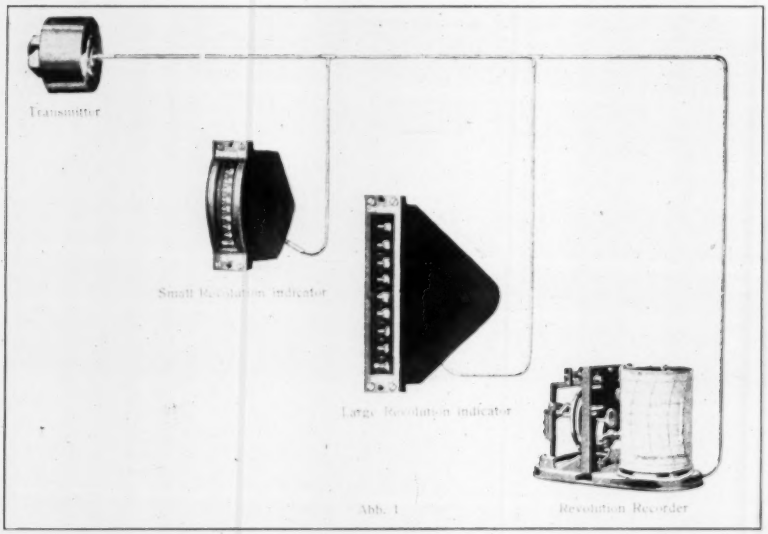


Fig. 529

the walls of the cylinder. The air pressure in the cylinder is measured by a pressure gage. Any force exerted on the piston causes it to descend and close up the annular slits. The air flowing into the cylinder from the air-pressure pipe through the throttle increases the internal pressure, until the product of this pressure by the piston surface is greater than the power P. The piston is consequently pushed out of the cylinder far enough to uncover the lower edge of the annular slit apertures. This allows the air to escape, and the pressure inside the cylinder continues to decrease until a state of equilibrium has been established between the force behind the piston and the internal pressure. As soon as the one or the other gains ascendancy, the piston and the internal pressure must come about automatically. The pressure bearing upon the piston can be read anywhere by means of a dial gage measuring the internal pressure. If the force behind the piston is obtained by the centrifugal action of a governor, the internal pressure will be a direct function of the centrifugal force and therefore of the number of revolutions per minute."

The characteristics are not stated. They probably are those of the centrifugal-weight principle, with complications. The reasons for adopting a pneumatic remote-reading system are interesting, as the discussion bears on the general subject of remote-reading speed-measuring instruments regardless of class or type. These reasons are stated as follows:

"The need for a good distant-reading tachometer has been felt for many years on account of the ever increasing number of large 'planes with their decentralized engine equipment . . . Even big firms are still in some cases using short-distance tachometers with flexible shafts

several meters in length for the lateral engines; an arrangement which will always lead to trouble . . . We have been investigating . . . We have found that (a) electrical transmission is too sensitive and cannot be rendered entirely independent of fluctuations in temperature; (b) hydraulic transmission suffers from the drawback of being subject to variations in the static pressure, beside the difficulty of making connections that are absolutely watertight.

"To make pipes and connections absolutely airtight and watertight is wellnigh impossible. If such a task is attempted, the pipes must be connected up permanently with the transmitter and receiver, with no possibility of separating them again afterwards. This makes it very difficult both to lay the connections and to execute any subsequent repairs . . . We soon realized that a condition precedent to the designing of a thoroughly serviceable distant-reading tachometer was a connection capable of being laid with ease and broken whenever required . . . Slight leakage in the connections must not interfere with the accuracy of the readings . . . the system must be unaffected by temperature changes, whilst remaining simple in design and easy to fit.

"Our new type of pneumatic distant-reading tachometer fulfills all these requirements. The *transmitter* is so small and so light that it can usually be connected direct to the point

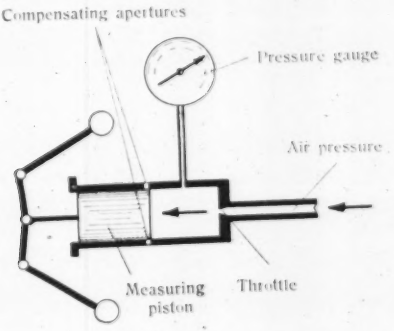


Fig. 530

where the piping ends. It is unaffected by changes in temperature. The *transmitting pipe* is made of thin aluminum and can be broken in as many places as desired. One or more minor leaks in the various connections will not affect the accuracy of the readings in any way. The *indicator* consists of a simple and strongly-built pressure gage of the type that has been familiar for years past.

"This offers the further advantage that it can have any number of indicators connected to it without re-calibration . . . "

The "Askania Automatic Recording Tachometer" is itself rather novel in principle. It is described as follows:

"The construction of this instrument is very simple. In front of a speedometer, the numbers of which are fixed like the type of a typewriter, is a ribbon and behind the ribbon the recording paper. At certain intervals, which can be adjusted at random, a magnet hammer controlled by a contact clock hits against the speedometer, thus printing on the recording paper the figure appearing at that particular moment. In order to avoid blurring of the printing of the quick moving unit column, the speedometer is stopped by a special device at the moment the figure is printed, catching up for the loss afterwards with the aid of a spring drawn taut. During the return of the hammer the paper and ribbon are moved forward. This action is regularly repeated so that the recording paper will be covered with a series of numbers, the difference between which represents the revolution for the set time interval. For the marking of special interesting time measures, an additional time signal can be given by means of a special contact device. If the revolutions of several motors are to be recorded at the same time one contact clock controls all instruments, thus obtaining absolute synchronism, which has heretofore been imposible with other tachometers."

The last sentence apparently refers to a feature brought out years ago in America by the Electric Tachometer Corporation and described above in Section 6.

8. Cross-pendulum

This class comprises ingenious modern modifications of the original fly-ball instruments. It includes several makes and numerous industrial models, both hand and stationary, both indicating and recording.

One basic idea of the cross-pendulum principle is to attain complete independence of position together with minimization of vibration. The design, in its simplest form, comprises *four* weights, located at the ends of two rigid arms whose centers are pivoted. The weights being equal and the proportions symmetrical, the two gravity effects are mutually compensating and the two arms will assume, at rest, any relative inclination whatever, from both vertical to both horizontal. This is the "static" compensa-

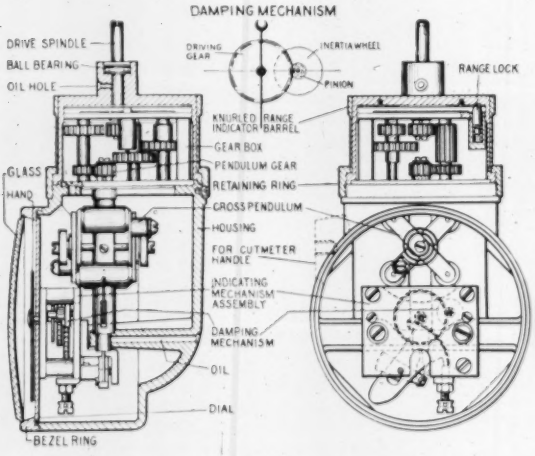


Fig. 531

Fig. 532

tion, and it would be effective with only one arm weighted at both ends and pivoted at the middle. The reason for two arms appears when we consider the dynamic behavior of the masses: The whole X arrangement turns with the main spindle and each arm tends to position itself at right angle to the spindle as soon as rotation starts, being restrained by the measuring spring. With only one arm weighted at its ends, we would get conditions of dynamic unbalance (somewhat like those of an unbalanced crankshaft) but with two arms the bending and vibration tendencies of each arm compensate those of the other, and the instrument runs smoothly.

Other Characteristics—As in the case of the fly-ball class, and for similar obvious reasons, zero is suppressed on the scales, which generally start at 25 percent of maximum reading. The accuracy depends on the make and the limit of error is usually well within one percent of full-scale value. Error being constant throughout, each instrument should preferably be used in the upper part of the scale. This is practicable with most hand instruments on the market, by reason of the quadruple, quintruple and even sextuple range gear shifts built into them, the ranges overlapping one another. High-grade instruments have individually graduated dials. Permanency of calibration of most commercial models is not seriously affected by wear, as they are adequately provided with hairsprings to take up backlash. Dynamic balance is excellent in most commercial forms, and the best

automotive and aircraft models are also balanced statically to prevent errors due to linear acceleration and deceleration. Even in the small models, the masses are large enough to preclude the measurement of sharply fluctuating speeds when the drive is metal-to-metal positive, but in this respect most cross-pendulum tachometers are better than fly-ball or tilting-ring tachometers. The temperature coefficient is usually slight. Proper lubrication is necessary. Lack of it ruins most older designs and constructions. Some of the newer instruments employ modern alloys, Bakelite and other materials, improved bearings, and other refinements. Response of pointer to small changes in speed is so nearly perfect that damping arrangements are purposely built into the high-grade sensitive instruments. This does not lessen accuracy and augments ease of reading.

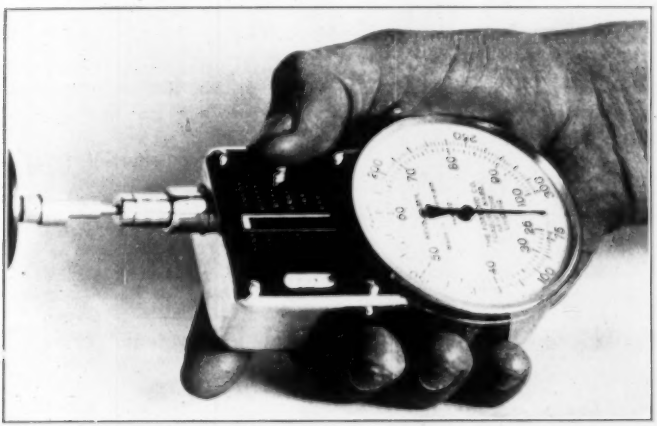


Fig. 533

A recently developed cross-pendulum instrument is the "O-Z Improved Tachometer" (O. Zernickow Co.). Fig. 531 (about two-thirds actual size) shows the construction in detail and deserves some study. It will be noted that the indicating element is actuated by the cross-pendulum with links operating the sliding plunger on opposite sides, which eliminates side friction. This instrument is said to be perfectly balanced statically and dynamically. It may be used in any position without possibility of variance of indications. It weighs 12 ounces. The rotating gear shift is an interesting feature, characterized by complete dust-proofing and by a wide travel from one range to the next. "The shifting is done in a . . . simple manner, by turning the tachometer barrel with the thumb and index finger of the hand holding the instrument, until the desired range is in line with the dial center and a spring lock is felt to engage inside." With the quintuple range gear shift, the scale values for the high range are exactly ten times those for the low range, with wide overlaps. The stationary form of this instrument has a six-inch dial. A modification of the hand form illustrated in Fig. 532 is supplied with a handle, with a disk attachment for the spindle; the dial is graduated somewhat differently, and this instrument is known as the "O-Z Cutmeter."

Another recent improvement in gear shifts features the new Foxboro "Multi Range Precision Hand Tachometer." The details of this instru-

ment are not available at this time (August 1931), but reference to a plurality of "masses" and to "the pendulum" in the preliminary description just released would indicate that it belongs in this Section. The gear shift provides no less than six ranges, with wide overlaps. Its small size is apparent from Fig. 533 and its gear mechanism is shown in Fig. 534. The description by the Foxboro Company is substantially as follows:

". . . A newly patented arrangement of the gearing in this instrument makes it available for use on practically any speed range. This enhances its usefulness since the same instrument can be used on every application throughout the plant . . . It reads directly in r.p.m. or feet per minute. Before pressing the tachometer spindle to the shaft it is necessary to see

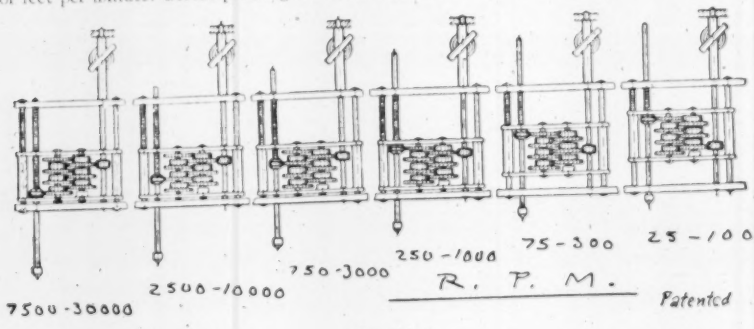


Fig. 534

that the sliding indicator is set at the maximum range, i.e., 7,500 - 30,000 r.p.m. This is extremely important as it prevents the instrument from being overranged. If the tachometer shows no reading on this range, it is necessary to merely press the setting button and slide

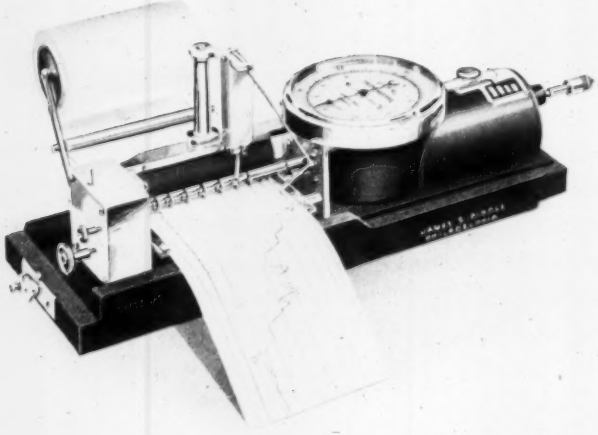


Fig. 535

the spindle into the next lower range. If no reading is obtained on this range, the operation is continued until the correct range has been reached. This entire operation can be performed with one hand, the thumb being used to press the setting button.

"Although the tachometer can be used in any position, extreme accuracy is secured when it is held horizontal. A spirit level is attached to each instrument to facilitate its leveling . . . The precision of this instrument is not affected by variations of temperature or position, or by magnetism.

"The arrangement of the gearing for the enlargement of the pendulum range is new and fully protected by patents. The gears for the six ranges are housed in a space smaller than the present housing on the four-range instruments.

"All Tachometers are provided with a damping device to obviate pointer flutter caused by slight deviations in speed. This assures a steady pointer but does not interfere with its accuracy."

The "Jagabi" Hand Tachograph (James G. Biddle Co.) is an interesting instrument of the cross-pendulum class—apparently the only speed recorder of such light weight that it can if necessary be held throughout a test lasting several minutes without tiring the operator. Fig. 535 shows all salient features. It embodies a cross-pendulum indicating hand tachometer which is slightly modified in order to actuate the pen of the strip-chart recorder. The tachometer has a quadruple gear shift which is regularly supplied in ranges up to 4000 or up to 8000 r.p.m. The recorder has a fountain pen and moves the chart optionally at $\frac{1}{4}$-inch or $\frac{1}{2}$-inch per second. This instrument is properly termed a tachograph because it continuously records instantaneous speed, including transient fluctuations. The chart range depends on the setting of the gear shift and its scale starts at 25 percent of full value.

9. Tilting-ring

This class comprises, in addition to the true ring pendulum type, all other instruments with a single crossbar weighted at its end and pivoted at its center about an axis transverse to the main spindle. A cross-pendulum tachometer as described in Section 8 but with two weights instead of four would belong here.

The industrial tilting-ring instrument was brought out by the Schaeffer and Budenberg Co. (merged in 1928 into the Consolidated Ashcroft Hancock Co.) A typical mechanism is shown in Fig. 536. The ring or governor is a heavy disk with a cross-shaped opening machined out of it. A spring holds this ring obliquely when at rest, opposes its tendency to place itself at right angle to the spindle when the spindle rotates, and is thus used to measure the speed.

Characteristics—The principle of measurement is inferential. Accuracy depends on properties of springs and varies widely in commercial models, small cheap instruments showing errors of several percent of maximum reading while many stationary tachometers for industrial plant service have a limit of error within two percent. High grade instruments must be individually calibrated. The scale is not quite uniform. Zero is suppressed. Scale ranges of ring instruments can be longer than those of the fly-ball and cross-pendulum classes but seldom start at less than ten percent of maximum reading. This class is well represented in stationary tachometers, both indicating and recording, that are giving excellent service. Response to decided fluctuations is rapid, but sluggishness (in fact actual "sticking") often prevents quick and sensitive response to small fluctuations. Good instruments have provisions for taking up back-lash due to wear. Wear is rapid in most instruments unless they are kept well lubricated. Inertia is comparatively great and its effects require that the great majority of stationary instruments be belt-driven. Most instruments are not balanced dynamically for all speeds, and are preferably used on steady speed applications. There are few hand tachometers of this class and some of them are not high-grade. The effects of temperature are often considerable. Most actual models must be used in one position.

Fig. 537 shows a stationary tachometer shortly to be brought out by the Consolidated Ashcroft-Hancock Co. (one of whose divisions brought out the first industrial tilting-ring tachometer). Its appearance is quite similar to that of the present models except for the absence of the familiar oil cup. This omission implies *the end of dependence on lubrication* which was heretofore inevitable with tilting-ring tachometers. The implication is correct:

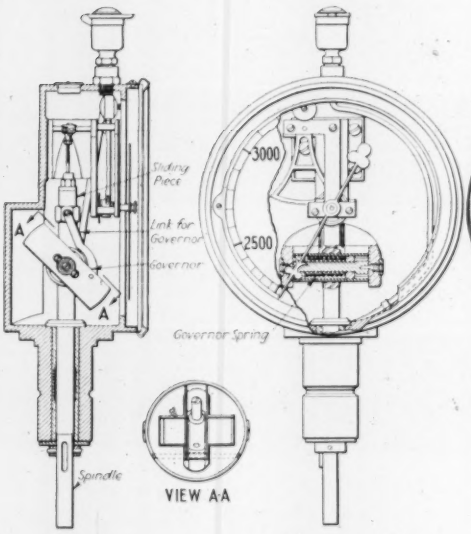


Fig. 536

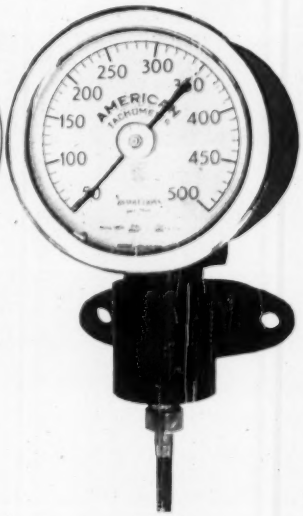


Fig. 537

although the details of this instrument are not available at this time (August 1931) the maker's engineering department has furnished a brief statement, the following extracts from which are pertinent:

"The new design . . . was developed with the following objects in mind. (1) Practically uniform scale graduation; (2) Reduction of wearing parts to a minimum; (3) Elimination of bearings requiring lubrication . . . The tachometer has a ball bearing spindle with grease pack ball bearings, which will run indefinitely without attention. There are no other bearings requiring lubrication . . . The sliding shaft is made of nitralloy; the fixed bearing at its end is a ball bearing of unique construction permitting both circumferential and axial motion. The motion of the sliding shaft is transmitted through a bakelite collar to a special ball bearing on the end of a spring arm fastened to the sector of a conventional gear and pinion movement. The spring arm being flexible prevents transmission of any shocks or sudden acceleration from the centrifugal pendulum system to the indicating device and reduces strain and wear on all parts. . . . The flexible arm also serves to dampen out small speed oscillations . . . "

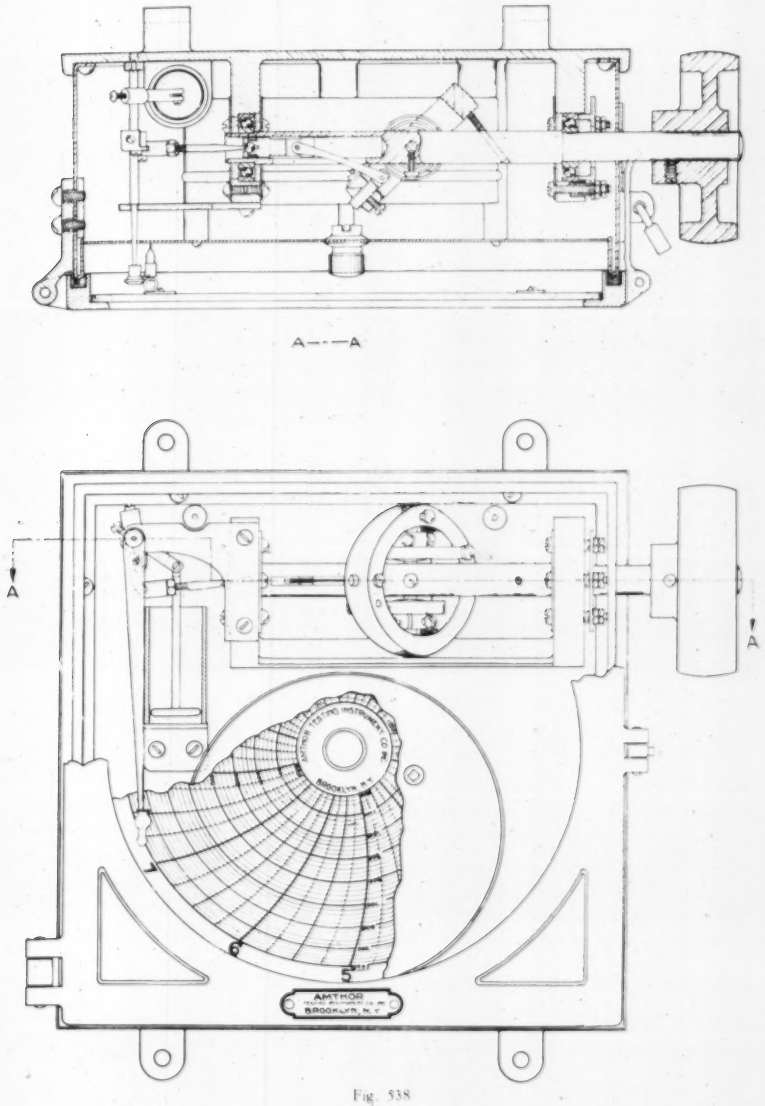


Fig. 538

Fig. 538 shows sectional views of a recording tachometer recently brought out by the Amthor Testing Instrument Co., in which several features are apparent. In order to reduce to a minimum the friction of the recording pen on the paper charts, the pen is a reservoir with a capillary tube which barely touches the paper without pressure. The main spindle runs in ball bearings and the sliding piece is connected to the pen mechanism by a ball joint. There is a dash-pot for damping pointer flutter without, however, preventing the accurate recording of speed variations.

10. Ball-and-cup

This class, though not yet represented in a line of industrial tachometers, deserves inclusion here for two reasons. One is that it is radically different in speed-measuring principle from the foregoing centrifugal-weight or "governor" classes; the other is that its principal inherent characteristics likewise differ. (A further reason is its obvious usefulness: this is no place for mere curiosities of instrumentation.)

The principle of speed measurement employed depends on the fact that a ball will "climb just so far" inside a spinning curved cup for each definite speed. In practice a rotating glass cup is used so that the path of the ball or balls will be visible. The outstanding characteristic is that the range depends on the radii and shape of the inside of the cup, so that given almost any desired scale, it is possible to calculate the dimensions and construct a cup that will realize the scale. Another characteristic is simplicity and consequent permanence of calibration and freedom from maintenance. Another is self-damping—amounting to inability to measure transient

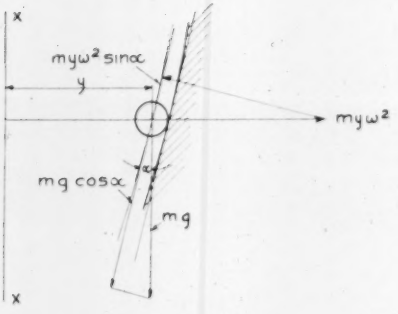


Fig. 539

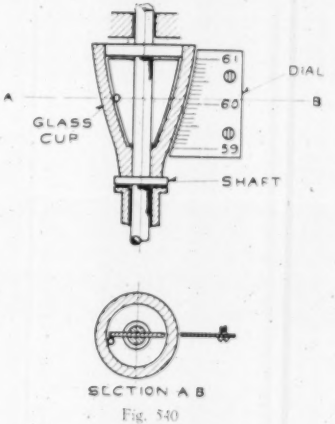


Fig. 540

fluctuations. In fact, the ball-and-cup tachometer appears to find its application to the measurement of high and steady speeds, so that it will undoubtedly be used mostly as a frequency meter. Other characteristics suggest themselves readily when one compares this class with others. This instrument is the invention of E. H. Greibach, Research Department, Westinghouse Electric & Mfg. Co., who described it in the August, 1929, A.I.E.E. *Journal*, from which the following is abstracted:

"A cup-shaped container, preferably transparent, rotates around a vertical axis. One or more balls of suitable material, such as steel, are placed inside the cup. These balls are subject to the influence of centrifugal forces as the cup rotates. The centrifugal force acting on each ball has a component in a direction tangential to the generatrix of the inside surface of the cup (Fig. 539). This component causes the ball to climb along the inside wall until it is counterbalanced by the component of weight acting in the opposite direction; or, in other words, the ball is in equilibrium on a point of the generatrix when the centrifugal force and gravity give a resultant which is perpendicular to the tangent. It is evident that the slope of the tangent is a function of the radius and the angular velocity of the cup. Therefore, when a cup is made whose slope and radius vary in a

proper manner, each point on the generatrix corresponds to a definite velocity for which the ball is at rest. By providing a stationary scale, properly graduated, the speed corresponding to each position of the ball can be read.

"The inside surface of the cup can easily be calculated to give any required scale distribution. For most applications a uniform scale is desirable. The calculation carried out for a speed indicator having a uniform scale distribution shows that it is very easy to build cups for a narrow scale range; i.e., cups which would indicate the speeds varying through a range of $\pm$ 2 per cent (or less) of a given speed. In the design of the cups, due consideration must be given to the rotary velocity of the cup. It can be shown that the curvature of the generatrix of the cup surface varies inversely as n_0. Since a greater curvature is desirable in the design of the glass cup, it is advisable to reduce the cup velocity by means of gears when designing indicators for high velocities . . .

"The cup must be set in vertical position to insure maximum accuracy . . . Precision in setting the cup, although desirable, is not essential for ordinary commercial purposes. If the cup is steep, this is true because for small angles of deviation from the vertical, the variation of the component of gravity parallel to the generatrix is negligible.

"A desirable feature of the apparatus is its property of indicating only the average when the speed undergoes rapid fluctuations. This characteristic is easily explained by remembering that the ball, however small, possesses a certain amount of inertia and that the effect of friction is negligible against the effect of inertia. Furthermore, it was found by experiment that on account of the friction being very small, the indicator acts sluggishly; i.e., the ball does not readily follow variations in the speed of the cup. Therefore it is necessary to provide a means of accelerating the ball. A convenient means is to use a transparent vertical plate inside of the cup, fastened to the shaft and extending, radially, close to the inner surface of the cup, as shown in Fig. 540.

"The indicator does not contain any parts that are subject to rapid wear or deterioration. It will maintain its calibration therefore, over an indefinite period of time. The logical application is for accurate indication of small variations in speed . . . When driven positively by a small synchronous motor, this instrument can be used as a precise frequency meter, having a full scale range corresponding to two cycles or less when based on 60 cycles . . . can be used to indicate frequency variations as low as one-tenth of one cycle. . ."

The instrument described above is solely an indicator: no recording, no remote-reading, no contactor for signalling high or low, no way of actuating a relay for automatic control, etc. Nevertheless one may conceive that the "plate" might be replaced by a transparent "spider" or set of radial fins — cross-section like the hub and spokes of a wheel — dividing the inside of the cup into six or more identical compartments. Six or more balls would cast a definite shadow and a photoelectric relay would do the rest. Another possibility that comes to mind is that for very close frequency control there could be a few degrees' loose play between spindle and spider, the latter held by a spring between the two stops, at each of which an electric contact would be made. At the set frequency the spider would float between the two stops; any variation would cause it to precess or to lag, thereby closing one of the two circuits.

Sections 11 to 14—CENTRIFUGAL FLUID

11. Centrifugal Liquid-cup

The simplest centrifugal fluid tachometer is a whirling glass partly filled with liquid. Inexpensiveness is the outstanding characteristic, it being a fairly simple matter to fasten a glass at the exposed top of a shaft. The shaft should be vertical—or approximately vertical in the case of high speeds. Only the case of a cylindrical glass will be considered, bowls and other shapes calling for mathematics outside the scope of a practical handbook. The following brief but adequate discussion is taken from Diederichs and Andrae:

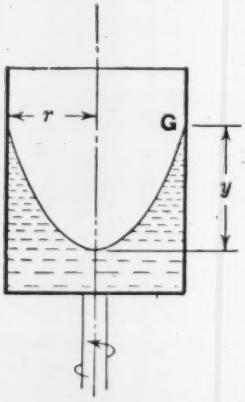


Fig. 541

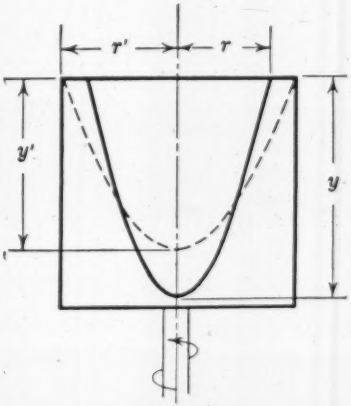


Fig. 542

The depression assumed by the whirling fluid (Fig. 541) is that of a paraboloid of revolution, and it can be shown that $y = \frac{C^2}{2g}$, where y is the height of depression and C the speed of revolution in feet per second, of a particle at G. Now $C = \frac{2\pi rn}{60}$, where r is the radius of the free surface in feet and n is revolutions per minute. Hence $y = \frac{\pi^2 r^2 n^2}{1800g}$. The value of this varies as the square of the speed and may be used as a measure of the speed. In the commonest forms of this type of tachometer a closed cup is used (Fig. 542). In this case, when a certain speed is attained the parabola will touch the side wall at the joint of the cover. After this speed is passed, the value of y becomes a linear function of the speed, that is, $y = \frac{\pi rn}{30}\sqrt{\frac{y'}{2g}}$, in which y' is the depth of the depression as the parabola touches the top of the cup.

12. U-tube

(Manufacturers' drawings delayed. This Section will appear next month)

13. Centrifugal Pump

Tachometers of this class consist of two elements, distinct in their purposes but generally assembled into one conveniently handled instrument. One element is a centrifugal device for producing a hydrostatic pressure that varies as the square of the speed; the other is a gage for measuring this pressure.

The primary device is a pump but it is employed solely as a differential pressure producer. Tachometers embodying pumps that actually pump volumes of liquid (the flow rate of which is then measured) constitute an entirely different class (Section 18). The centrifugal pump tachometers here considered usually embody a simple paddle wheel having perfectly radial blades so that the pressure differential between center and periphery will be the same, for any given speed, regardless of direction of rotation. The differential varies almost exactly as the square of the speed over the useful range. In the particular instrument illustrated (Fig. 543), the ratio of height of liquid to r.p.m. is the 2.05 power, approximately.

The pressure gage does not necessarily have to be of any particular type, but in practice it is a single-tube manometer rising from the reservoir connected to the "delivery side" of the centrifugal pump. Since atmospheric pressure is allowed to act both on the top of the liquid column and on the liquid in the "intake side" reservoir, the height of the column is a true measure of the differential produced by the primary device. It follows that the accuracy and some other characteristics of this class of tachometers are those of the single-tube liquid-column manometer—an instrument which is almost ideally suitable for the purpose, unless one considers a limitation the fact that it does not convert into a uniform scale the square root scale of r.p.m. imposed by the characteristics of the centrifugal primary device, and except for inability to be used in any position. The length of the glass tube determines the precision of readings. With a 36-inch tube, this precision can easily be 0.03 inch or 0.1 percent of the maximum differential. It is constant, while the speed scale is progressive. Consequently, speed values can be read very finely in the upper part, while in the lower part—as usual with square-root scales—the least personal or parallax error is greatly multiplied in terms of speed. Centrifugal pump tachometers should therefore be used preferably in the upper part of their ranges, where the limit of error even with a short manometer is usually well within 0.5 percent.

As with all progressive-scale instruments, the range is narrow, but suitable gear shifts can be built in.

The energy consumed varies also as the square of the speed. It usually amounts to a fraction of a horse-power. It naturally disqualifies the instrument for use on light machinery.

No hand tachometers can be made but most instruments are semi-portable, i.e., easily transportable but requiring to be screwed down in place. They are preferably used as stationary tachometers on applications where speed does not fluctuate widely. They are reliable, give no trouble and seldom have to be returned to the factory for adjustments.

Fig. 543 shows the best known American-made instrument of this class, the Veeder Tachometer (Veeder-Root Inc.). Extracts from maker's description:

The Form H-4 Tachometer is a portable instrument for indicating revolutions per minute of dynamos, motors, shafting, etc. It is simply a centrifugal pump, a reservoir for liquid and an indicating tube. The only moving part is the paddle wheel in the centrifugal pump. This has radial blades and hence, indicates when run in either direction. When the paddle wheel is revolved, the liquid is forced out of pump and up the indicating tube by centrifugal force. The reservoir is connected by balanced openings to the center of the pump and the liquid is discharged through balanced openings in its periphery.

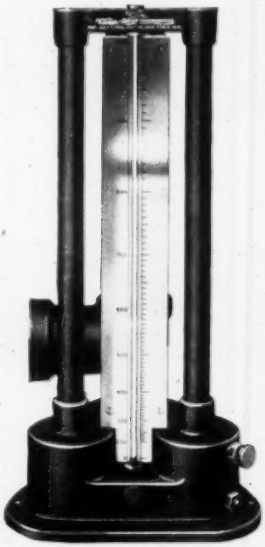


Fig. 543

The graduations on the scale illustrated (Fig. 543) represent variations of speed of one per cent at top. A skilled observer can easily read the indications to within one-tenth of one per cent from maximum down to three-fifths of maximum. Special scales with fine graduation can be furnished. This instrument is used by the Bureau of Standards at Washington, D. C.

A slight inclination of the instrument does not appreciably vary its reading. The shaft of the paddle wheel is vertical so that no stuffing box is necessary. The paddle shaft is driven through bevel gears from a horizontal shaft carried in ball bearings. The housing for this driving shaft can be rotated on a vertical axis through more than 180° so that the instruments can be belted or geared from any direction. The vertical position of the paddle also serves to quickly eliminate any air bubbles which might be entrained in the liquid when the instrument is filled.

A displacement plunger is provided for adjusting the level of the liquid to zero when it is at rest. There is a valve for throttling the passage from the pump to the indicating tube but this is used only when the speed varies suddenly. Kerosene colored with aniline dye is the liquid used. A supply of colored kerosene is furnished with each instrument.

The standard size is a 12″ scale, but for testing instruments we can furnish them with scales 36 inches high.

The Amyot-le Prieur tachometer, a French instrument, represents a different type in this class. The paddle-wheel intake is connected to a reservoir open to atmosphere but the delivery side is connected to a closed chamber. The air above the liquid surface in this chamber is compressed when the impeller rotates. This pressure is indicated or recorded at a distance by one or more instruments, somewhat like the German system shown in Fig. 529. Air-tight connections are necessary but once installed the tachometer requires practically no attention, as the same oil which is the centrifugal element serves also as lubricant.

14. Pneumatic

In this class of centrifugal fluid tachometers, the method resembles that of the centrifugal pump class described in the previous section, in that there is a primary device for producing a difference of pressure and a manometer for measuring it.

The usual primary device embodies a tee of piping, rotating about the axis of the central pipe so that air tends to be expelled from the two arms. The measuring instruments are of various classes and types according to the requirements of the application.

Characteristics—Square-root scale, etc. as in previous class, but uniform-scale records can be obtained (see below). Remote-reading and remote-recording instruments practicable and available. Primary devices (of

makes designed for industrial purposes) are rugged and trouble-free. Differential is usually only a few inches of water. No portable models. Wide field of applications, steady or fluctuating speeds, excluding however all where power consumption would falsify measurements. Accuracy depends mostly on pressure measuring instruments. Calibration is permanent as far as primary devices are concerned. Leakages destroy accuracy but they can be readily detected. Direction of rotation immaterial.

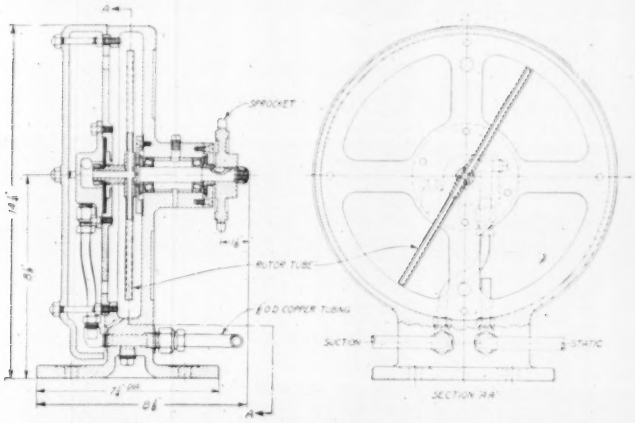


Fig. 544

Mention may be made of inverted-tee primary devices with the central pipe ending in an annular liquid seal, and with other refinements, but the Bailey Tachometer (Bailey Meter Co.) is the outstanding *industrial* instrument and its description will serve adequately for the pneumatic class.

The actual construction consists of a tube mounted in bearings and driven directly by suitable couplings, by sprockets and chain or by gears. At the end of this tube is a hollow cross piece making a letter T. Rotation produces a suction due to centrifugal force tending to throw the air out of the arms of the T. Fig. 544 shows the primary device, known as the rotor.

There is no flow of air through the system, but simply a differential in air pressures produced, which is applied, in the case of the recorder, Fig. 545, under two oil sealed bells which are hung from a beam in the recording mechanism. The two bells are suspended from knife edges on the beam which is also supported by knife edges, and is connected by a link to the recording pen yoke as shown in the figure. The movement of the pen is directly proportional to the differential pressure which varies nearly exactly as the square of the rotor speed, and a pen motion directly proportional to the tachometer rotor speed is produced by using a parabolic displacer suspended in a reservoir of mercury as shown in Fig. 545. An increase in rotor speed is accompanied by a greater pressure difference, which, acting on the bells, produces motion of the pen yoke beam, thereby drawing the displacing member out from its mercury reservoir. This member moves until its change in buoyancy exactly balances the force produced by the pressure difference in the bells. The shape of the displacer is such that its motion and that of the recording pen are directly proportional to the tachometer rotor speed, thereby allowing the use of a uniformly graduated chart for recording speed.

The radius of the displacing member from the point about which its supporting beam rotates can be changed to give a maximum chart reading over a wide range in rotor speed. For maximum speeds as low as 200 r.p.m. and as high as 3000 r.p.m. the simple rotor with chain and sprocket drive is used. For cases where full chart or full scale motion must be produced with slower speeds, the geared type tachometer rotor is used for maximum speeds as 100 seconds per revolution. Speeds up to 6000 r.p.m. can be handled by the geared type rotor.

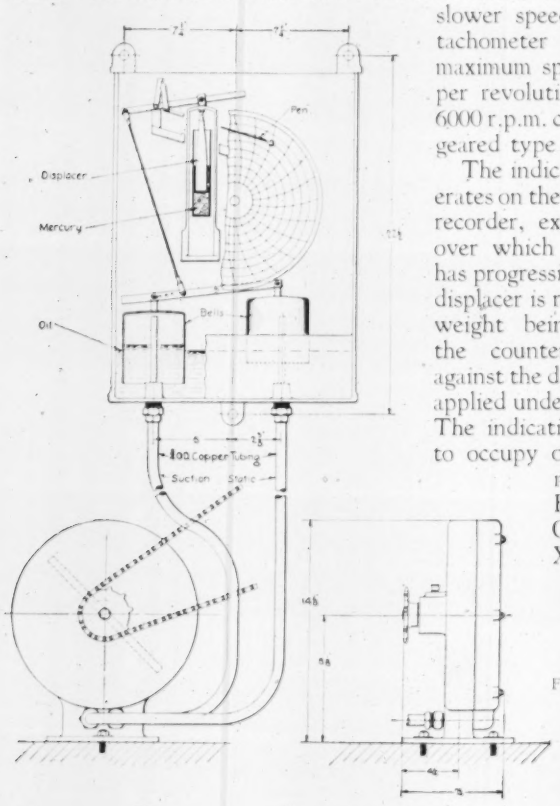


Fig. 345

The indicating tachometer operates on the same principle as the recorder, except that the scale over which the pointer travels has progressive graduations. No displacer is required, a pendulum weight being used to supply the counterforce which acts against the differential pressure as applied under the oil-sealed bells. The indicating unit is designed to occupy one of the compartments in a standard Bailey Multi-Pointer Gage (see Chapter XI, Section 8).

The recording type tachometer is used with the Bailey Boiler Meter to record the rate of coal feed. The tachometer rotor can be attached to either the stoker shaft or the pulverized coal feeder, so that it records the rate of coal feed. When used in this connection the record is easily compared with the records of Steam Flow and Air Flow on the Boiler Meter chart, and aids the firemen in adjusting the rate of coal feed in accordance with the variations in boiler rating.

For installations where it is desirable to have non-uniformly graduated charts on the recorders so that certain portions of the scale may be enlarged to provide for accuracy in operation, the Bailey recording tachometer is supplied with a pendulum counterweight instead of a displacer and mercury reservoir.

All records are made on 12-inch circular charts which can be furnished with one-, 12-, or 24-hour period. Seven-day charts can also be furnished.

Measurement of Air Flow

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CHAPTER VII (Cont'd

Effect of a Fluctuating Wind. — We have tacitly assumed in the preceding analysis that the anemometer is placed in a steady wind whose speed is constant and uniform across the whole vane circle. In practice, however, the wind speed is usually both more or less unsteady in magnitude and variable from point to point across the vanes, and it is necessary to consider what errors may be incurred from each of these causes. We will deal firstly with the effect of a fluctuating wind speed, which we will assume at any instant to be the same at all points over the vane circle, but to vary with time over the whole circle. We must exclude from consideration natural winds, and confine our attention to those cases in which an anemometer is used to measure the speed of an artificially produced air current. Such a current will usually be obtained by means of a fan running at a speed which is intended to be constant, but which will probably fluctuate about a mean value. As a consequence the wind speed will also fluctuate in a more or less periodic manner about a mean value, and for the purpose of analysis we will assume that the wind speed V at any time t is given by the simple harmonic relation,

$$V = V_0(1 + \lambda \sin pt), \quad . \quad . \quad . \quad (21)$$

where V is the value of V at any time $t = 0$.

It should be noted that in this equation λ is the amplitude of the fluctuation, V_0 is the mean speed about which fluctuations occur, and that $\frac{2\pi}{p}$ is the time for one complete cycle.

Now the aerodynamic theory of airscrews has established the fact that both for an airscrew producing a wind, and for a windmill driven by the wind, the wind torque Q is given by an equation of the form

$$\frac{Q}{\rho V^2 D^3} = f\left(\frac{nD}{V}\right), \quad . \quad . \quad . \quad (22)$$

where $f\left(\frac{nD}{V}\right)$ represents some function of $\left(\frac{nD}{V}\right)$. We may there-

fore assume that an equation of this type holds for a vane anemometer. When the anemometer is in steady motion $Q = -T$, and therefore by plotting $-\frac{T}{\rho V^2 D^3}$ against $\frac{nD}{V}$ the form of the function $f\left(\frac{nD}{V}\right)$ can be determined. To take a concrete case, we may consider once more the low-speed anemometer,* for which the values of T have been calculated (see Table VIII.). Values of Q ($= -T$) are plotted against $\frac{nD}{V}$ in Fig. 44, and it will be seen that all the points for values of V = 1·0 and upwards lie on a straight line. It should be noted that this range of V corresponds with the linear portion of the calibration curve

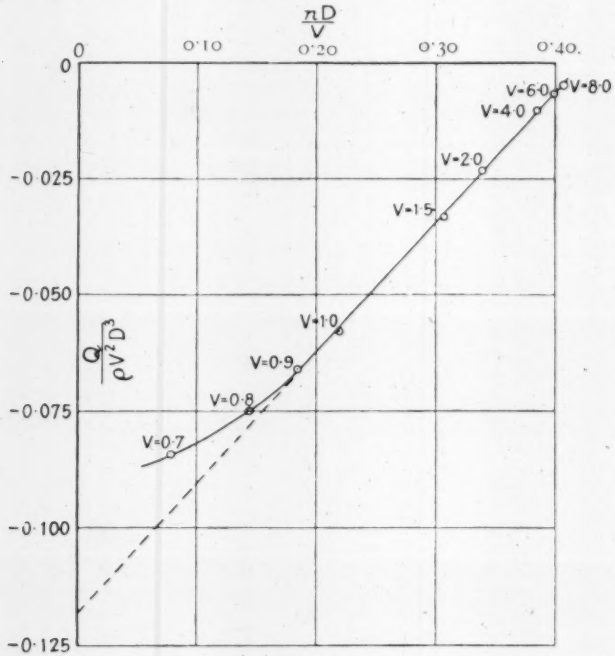


FIG. 44.

of the instrument, so that it appears that over this region we may write

$$\frac{Q}{\rho V^2 D^3} = a + b\frac{nD}{V}, \quad . \quad . \quad . \quad (23)$$

* Continual reference to this anemometer is necessary, since it is the only instrument whose complete characteristics are available to the author.

where a and b are constants, and this result may be expected to apply, over the linear range, to all vane anemometers of normal design, the values of a and b varying from one to another. For the particular instrument under consideration the values of a and b taken from Fig. 44 are $-0{\cdot}118$ and $+0{\cdot}383$ respectively.

Let us now imagine the fluctuating wind speed given by equation (21) suddenly impressed upon an anemometer which was previously rotating at a steady rate n_0 in a steady wind of speed V_0.

From equation (13) we have, at time $t = 0$,

$$Q_0 = \rho V_0^2 D^3 \left(a + b\frac{n_0 D}{V}\right),$$

and at a time t shortly after

$$Q_1 = Q_0 + q = \rho(V_0 + \bar{v})^2 D^3 \left\{a + b\frac{n_0 + n}{V_0 + \bar{v}} D\right\}$$

where q, $\bar{v}$, and n are small changes in Q_0, V_0 and n_0 respectively. Hence, by subtraction,

$$\frac{q}{\rho D^3} = 2aV_0\bar{v} + a\bar{v}^2 + bD(V_0 + \bar{v})(n_0 + n) - bDn_0V_0$$

$$= bD(V_0 + \bar{v})n + \bar{v}(2aV_0 + bDn_0) + a\bar{v}^2.$$

Now $\bar{v}$ is the increase in wind speed, and is given by $\lambda V_0 \sin pt$, so that, substituting this value of $\bar{v}$ in the above equation, we have

$$\frac{q}{\rho D^3} = bDV_0(1 + \lambda \sin pt)n + \lambda V_0(2aV_0 + bDn_0) \sin pt + a\lambda^2 V_0^2 \sin^2 pt.$$

Since q is the excess wind torque acting on the instrument, which produces an increase n in the rotational speed, the equation of motion, which is given by

$$I\frac{d}{dt}(\text{angular velocity}) + q = 0,$$

becomes, since the angular velocity produced by q is equal to $2\pi n$,

$$\frac{2\pi I}{\rho D^3}\frac{dn}{dt} + bDV_0(1 + \lambda \sin pt)n = -(2aV_0 + bDn_0)\lambda V_0 \sin pt - a\lambda^2 V_0^2 \sin^2 pt,$$

or

$$\frac{dn}{dt} + \alpha(1 + \lambda \sin pt)n = \beta \sin pt + \delta \sin^2 pt, \quad . \quad (24)$$

$$\left.\begin{aligned} \text{where} \quad a &= \frac{b\mathrm{D}\mathrm{V}_0\rho\mathrm{D}^3}{2\pi\mathrm{I}}, \\ \beta &= -\frac{\lambda\mathrm{V}_0(2a\mathrm{V}_0 + b\mathrm{D}n_0)\rho\mathrm{D}^3}{2\pi\mathrm{I}}, \\ \text{and} \quad \delta &= -\frac{a\lambda^2\mathrm{V}_0^2\rho\mathrm{D}^3}{2\pi\mathrm{I}}. \end{aligned}\right\} \qquad (24a)$$

Equation (24) is of the standard form $\frac{dy}{dx} + \mathrm{P}y = \mathrm{Q}$, where P and Q are functions of x, and the solution is therefore

$$ne^{\int a(1+\lambda \sin pt)\,dt} = \int (\beta \sin pt + \delta \sin^2 pt)e^{\int a(1+\lambda \sin pt)dt}\,dt + \mathrm{C},$$

$$\text{or } ne^{a(t-\frac{\lambda}{p}\cos pt)} = \int (\beta \sin pt + \delta \sin^2 pt)e^{a(t-\frac{\lambda}{p}\cos pt)}dt + \mathrm{C}, \qquad (25)$$

where C is a constant.

This solution cannot be reduced further without making certain assumptions based on practical considerations. We have assumed that the wind speed varies according to a sine law about a mean value V, but we have not yet assigned magnitudes to the amplitude or period of the variation.

For the purpose of illustration we will assume that the frequency is 2 per second (i.e. the periodic time is $\frac{1}{2}$ second) and the amplitude $\pm$ 10 per cent. of the mean speed. These assumptions are more or less representative of many working conditions. Hence in equation (21) we have

$$p = \frac{2\pi}{\frac{1}{2}} \text{ and } \lambda = 0{\cdot}1,$$

i.e.

$$\frac{\lambda}{p} = 0{\cdot}008.$$

Equation (25) then becomes

$$ne^{a(t-0{\cdot}008\cos pt)} = \int (b \sin pt + \delta \sin^2 pt)e^{a(t-0{\cdot}008\cos pt)}dt + \mathrm{C}.$$

Now the maximum value of 0·008 cos pt is 0·008, so that when $t = 0{\cdot}8$, i.e. before the motion has proceeded for one second, this term becomes less than 1 per cent. of t, and afterwards becomes relatively smaller. It is therefore legitimate to neglect 0·008 cos pt in comparison with t and we may write, with sufficient accuracy,

$$ne^{at} = \int (\beta \sin pt + \delta \sin^2 pt)e^{at}dt + \mathrm{C},$$

the right-hand side of which can now be integrated, giving, after reduction,

$$n = \frac{\beta(a \sin pt - p \cos pt)}{a^2 + p^2}$$

$$+ \frac{\delta(a^2 + 4p^2 - a^2 \cos 2pt - 2ap \sin 2pt)}{2a(a^2 + 4p^2)} + Ce^{-at} . \quad . \quad (26)$$

The value of C can be obtained by putting $n = 0$ when $t = 0$, since n is the change in the rotational speed of the vanes from its value at the commencement of the fluctuating motion, and in this way we arrive at the complete solution,

$$n = \frac{\beta(a \sin pt - p \cos pt)}{a^2 + p^2}$$

$$+ \frac{\delta(a^2 + 4p^2 - a^2 \cos 2pt - 2ap \sin 2pt)}{2a(a^2 + 4p^2)}$$

$$+ pe^{-at}\left[\frac{\beta}{a^2 + p^2} - \frac{2\delta p}{a(a^2 + 4p^2)}\right]. \quad (27)$$

If we examine this solution we find that the motion may be regarded as composed of two parts, one a steady periodic motion represented by the sum of the first two terms, and the other, represented by the term Ce^{-at}, a damped motion which has its maximum value when $t = 0$ and decays rapidly as the time proceeds. In the case of the low-speed anemometer we find from (24*a*), by inserting the values of the mechanical constants already given, that $a = 0{\cdot}718V_0$, so that if we take the case when $V_0 = 1$ foot per second, the damped part of the motion is equal to $Ce^{-0{\cdot}718t}$. Now $e^{-0{\cdot}718t}$ becomes equal to 0·1 when $t = 3{\cdot}2$ approximately, so that the damped motion is reduced to one-tenth of its initial amplitude in about $3\frac{1}{8}$ seconds, and it will be seen that this time will decrease as V increases. It appears therefore that the motion represented by (27) rapidly assumes a steady periodic character given by the sum of the first two terms, and it can easily be shown that the average value of n is $\frac{\delta}{2a}$, or, when the values of δ and a from (24*a*) are inserted, $-\frac{a\lambda^2}{2bD}V_0$.

In other words, this means that the anemometer, when placed in a wind fluctuating in the assumed manner about a mean value V_0, will rotate at an average rate higher by an amount $-\frac{a\lambda^2}{2bD}V_0$ (higher, since a is negative) than the rate

at which it would rotate in a steady wind of speed V_0; i.e. an anemometer in a fluctuating wind gives readings in excess of the mean speed.

It will be seen that the quantity $-\frac{a\lambda^2}{2bD_0}$ is independent of the period of the fluctuations in the wind speed and of the moment of inertia of the vanes. It appears that these quantities will merely determine the lag of the periodic motion of the vanes behind that of the wind, whilst the mean amplitude of the motion of any given set of vanes is affected only by the amplitude of the variations of the wind speed. An inspection of (27), however, shows that the *actual* value of n at any time is influenced by p and I; it is only the *average* value of n that is independent of these quantities.

To obtain some idea of the magnitude of the excess reading obtained in a fluctuating wind, we may apply this result to the low-speed anemometer. The values of a and b have already been given as $-0{\cdot}118$ and $0{\cdot}383$ respectively, and the value of D will be found in the list of constants for this instrument. The value of $-\frac{a\lambda^2}{2bD}V_0$ will be found to become $0{\cdot}00493V_0$, on the assumption, as before, that $\lambda = 0{\cdot}1$. We can now draw up the following table in which the value of $0{\cdot}00493V_0$ is shown for various values of V_0; the value of n_0 corresponding to each value of V_0 was obtained from the calibration curve of the instrument obtained in a steady wind, and the last column, in which $0{\cdot}00493V_0$ is expressed as a percentage of n_0, shows the percentage increase in the readings of the instrument when placed in the fluctuating wind of mean speed V_0.

It will be seen that for the conditions assumed the percentage error on the mean speed is less than 1 per cent. If, therefore, the maximum departure of the wind speed from its mean value does not exceed 10 per cent., and the frequency of the fluctuations in wind speed is not greater than 2 per second, the errors in the mean speed as indicated by an anemometer may be disre-

TABLE IX.

V_0 Feet per Second.	$0{\cdot}00493\ V_0$ Revs. per Second.	n_0 Revs. per Second.	Percentage Increase in Reading of Anemometer.
1	0·00493	0·70	0·70
2	0·00986	2·16	0·46
4	0·0197	4·92	0·40
6	0·0295	7·53	0·39
8	0·0394	10·42	0·38

garded. It will in many cases be found that unsteadiness in the air current is not worse than that here assumed. In adverse circumstances, however, the maximum amplitude of the fluctuations may be as much as 50 per cent. ($\lambda = 0{\cdot}5$) or more in excess of the mean speed, although it is unlikely that the frequency of the fluctuations will be much higher than 2. Such extremely unsteady conditions sometimes occur in mine drifts. Since the error in the readings of the anemometer have been shown to be proportional to λ^2, they will be increased 25 times if λ is 0·5 instead of 0·1, so that under such unfavourable conditions the readings may be 10 per cent. high, or even more.

Effect of a Variation in Wind Speed Across the Vane Circle.—In general the distribution of velocity across a pipe along which air is flowing is not uniform, the velocity being higher at the centre than near the walls. We have seen in Chapter V. that, in order to determine the quantity of air flowing in such a case, the velocity has to be measured at certain definite radii, which are the mean radii of a number of imaginary concentric zones of equal area into which the pipe has to be divided in making measurements. The question therefore arises whether, when measurements are made by means of an anemometer, the instrument must be placed with its axis at the radii in question or at other points. The answer depends on whether or not the blades will rotate at the speed appropriate to the velocity of the filament of air passing the centre of the anemometer disc, or at a rate corresponding to some other wind speed.

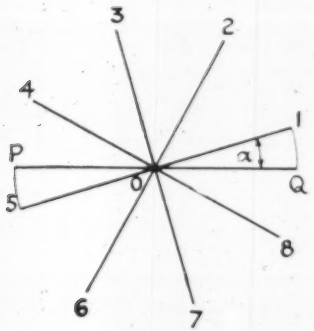


FIG. 45.

In Fig. 45 let 01, 02, 03, etc., represent the median lines of the vanes of an eight-bladed anemometer, and let r be the radius to the centre of pressure of a blade. Let blade 01 be at an angle α to the reference line PQ, and let the velocity vary along PQ according to the relation

$$V = V_0(1 + Ax + Bx^2), \quad . \quad . \quad . \quad (28)$$

where V is the velocity at any point along PQ, distant x from P where the velocity is V_0.

Also let $PO = OQ = r$.

Let x_1, x_2, etc., be the distances measured parallel to PQ of the centres of pressure of the blades 01, 02, etc., from O.

Then

$$x_1 = r(1 + \cos\alpha)$$

$$x_2 = r\left(1 + \cos\overline{\frac{\pi}{4} + \alpha}\right)$$

$$x_3 = r\left(1 + \cos\overline{\frac{2\pi}{4} + \alpha}\right) = r(1 - \sin\alpha),$$

and $$x_4 = r\left(1 + \cos\overline{\frac{3\pi}{4} + \alpha}\right) = r\left(1 - \sin\overline{\frac{\pi}{4} + \alpha}\right);$$

similarly

$$x_5 = r(1 - \cos\alpha),$$

$$x_6 = r\left(1 - \cos\overline{\frac{\pi}{4} + \alpha}\right),$$

$$x_7 = r(1 + \sin\alpha),$$

and

$$x_8 = r\left(1 + \sin\overline{\frac{\pi}{4} + \alpha}\right).$$

In order that the problem may not become unduly complicated, we shall assume that the velocity distribution perpendicular to PQ is uniform, i.e. that the velocity at all points on a line intersecting PQ and perpendicular to it is the same, and equal to the velocity at the point of intersection. In this case the velocities V_1, V_2, etc., of the air impinging on the centre of pressure of each blade depend only upon the distances x_1, x_2, etc., and are given by the following relationships :—

$$\left.\begin{aligned}
V_1 &= V_0[1 + Ar(1 + \cos\alpha) + Br^2(1 + \cos\alpha)^2],\\
V_2 &= V_0\left[1 + Ar\left(1 + \cos\overline{\frac{\pi}{4} + \alpha}\right) + Br^2\left(1 + \cos\overline{\frac{\pi}{4} + \alpha}\right)^2\right],\\
V_3 &= V_0[1 + Ar(1 - \sin\alpha) + Br^2(1 - \sin\alpha)^2],\\
V_4 &= V_0\left[1 + Ar\left(1 - \sin\overline{\frac{\pi}{4} + \alpha}\right) + Br^2\left(1 - \sin\overline{\frac{\pi}{4} + \alpha}\right)^2\right],\\
V_5 &= V_0[1 + Ar(1 - \cos\alpha) + Br^2(1 - \cos\alpha)^2],\\
V_6 &= V_0\left[1 + Ar\left(1 - \cos\overline{\frac{\pi}{4} + \alpha}\right) + Br^2\left(1 - \cos\overline{\frac{\pi}{4} + \alpha}\right)^2\right],\\
V_7 &= V_0[1 + Ar(1 + \sin\alpha) + Br^2(1 + \sin\alpha)^2],\\
\text{and}\quad & \\
V_8 &= V_0\left[1 + Ar\left(1 + \sin\overline{\frac{\pi}{4} + \alpha}\right) + Br^2\left(1 + \sin\overline{\frac{\pi}{4} + \alpha}\right)^2\right].
\end{aligned}\right\} \quad (29)$$

Let the centres of pressure of the blades move, under the effect of this variable velocity, at a tangential linear speed $\bar{v}$ which would correspond, according to the calibration curve, to

a wind speed $\bar{V}$. Then $\bar{V}$ and $\bar{v}$ will be such that the torque on the whole instrument rotating at this speed will be equal to the sum of the individual torques contributed by each blade.

Now we have already shown (equation (4)) that

$$\text{Torque} = K\rho A\phi(V^2 + v^2)mr\cos(\theta - \phi + \gamma).$$

Provided that the wind speed is such that the anemometer is rotating at a fair speed, i.e. that we are working on a portion of the calibration curve some distance from B in Fig. 40, no appreciable error will be introduced by assuming that ϕ, and hence also K and γ, are constant for all the blades, so that we may write

$$\text{Torque} = K'm(V^2 + v^2)$$

The condition that the total torque is equal to the sum of the torques of all the blades is, therefore, expressed by the equation

$$8K'(\bar{V}^2 + \bar{v}^2) = K'\{(V_1^2 + \bar{v}^2) + (V_2^2 + \bar{v}^2) + \ldots + (V_8^2 + \bar{v}^2)\},$$

i.e.

$$8\bar{V}^2 = V_1^2 + V_2^2 + V_3^2 + \ldots + V_8^2 = \Sigma V_1^2.$$

From equations (29) it will be found, after reduction, that

$$\Sigma V_1^2 = 8V_0^2[(1 + Ar + Br^2)^2 + \frac{r^2}{8}(4A^2 + 8B + 24ABr + 27B^2r^2)],$$

which is independent of a and hence constant for all positions of the blades, so that

$$\bar{V} = V_0\sqrt{(1 + Ar + Br^2)^2 + \frac{r^2}{8}(4A^2 + 8B + 24ABr + 27B^2r^2)}. \qquad (30)$$

In this equation $\bar{V}$ is, as we have seen, the wind speed indicated by the anemometer. If the instrument indicated the speed of the wind passing through the centre of its disc, the value of $\bar{V}$ would be $V_0(1 + Ar + Br^2)$, so that it appears that the indicated wind speed is the speed of the air at some point along the radius of the anemometer.

To get some idea of the magnitude of the discrepancy, we must take numerical examples. Let us assume, in order to fix our ideas, that the wind speed given by equation (28) is V_0 at P($x = 0$ in Fig. 45), and rises to $2V_0$ at Q ($x = 2r$), and that at $x = r$, the centre of the disc, $V = 1{\cdot}8V_0$. We can now calculate the values of A and B, and, by inserting these in equation (20), we get

$$\bar{V} = 1{\cdot}69V_0,$$

which is 6 per cent. less than the velocity at the centre of the disc, and is, in fact, the velocity at the point $x = 0{\cdot}81r$, instead of at $x = r$.

If the diameter of the anemometer is small compared with that of the pipe, it will probably be sufficiently accurate to assume a linear variation of velocity across the disc of the form

$$V = V_0(1 + Ax).$$

In this case, similar reasoning leads to the result

$$\bar{V} = V_0\sqrt{(1 + Ar)^2 + \frac{A^2r^2}{2}},$$

and, on the assumption, as before, that the velocity at $x = 2r$ is twice the velocity at $x = 0$, we have

$$\bar{V} = 1{\cdot}54V_0 = \text{velocity at the point } x = 1{\cdot}08\,r;$$

i.e. $\bar{V}$ is $2\frac{1}{2}$ per cent. greater than the velocity at the centre of the disc.

In practice, provided that the pipe diameter is reasonably large in relation to that of the anemometer, a distribution of velocity such as that assumed in both the above cases, in which the wind speed at the centre of pressure of a blade in one of its extreme positions is double its value in the other, is probably of rare occurrence, so that in general the errors in indicated wind speed will be less than those given above. Nevertheless, it is important to observe that these errors may in many cases become appreciable, and it is for this reason that it is not advisable to use an anemometer in a pipe whose diameter is less than about 6 times that of the instrument, unless it is known, either from a preliminary exploration or otherwise, that the distribution of velocity across the section of measurement is reasonably uniform.

The Meriam Company, 1955 West 112th St., Cleveland, Ohio, manufacturers of Flow Meters, Draft Gages, Filter Flow Meters, "U" and Well Type Manometers and Pulsation Shock Absorbers for pressure gages, announce the appointment of Mayer & Oswald, 332 outh LaSalle St., Chicago, Ill., as its sales representative in the Chicago territory.

The Cla: d S. Gordon Company who recently installed a new commercial X-ray laboratory at 2416 West 15th Place, Chicago, Illinois, announce the appointment of Wm. G. Praed as Radiograph Engineer in charge of this laboratory.

Mr. Praed was with the Bethlehem Steel Company during the war working on gun sight layouts. After the war he went with the Link-Belt Company of Indianapolis as tool maker and worked his way up through the Engineering Department, Estimating Department, Night Superintendent, Works Engineer, and when he left them was Assistant to the General Superintendent. He has been identified with the American Society for Steel Treating ever since its organization and was twice chairman of the Indianapolis section. He has had a great deal of experience with the inspection and testing of metals.

NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

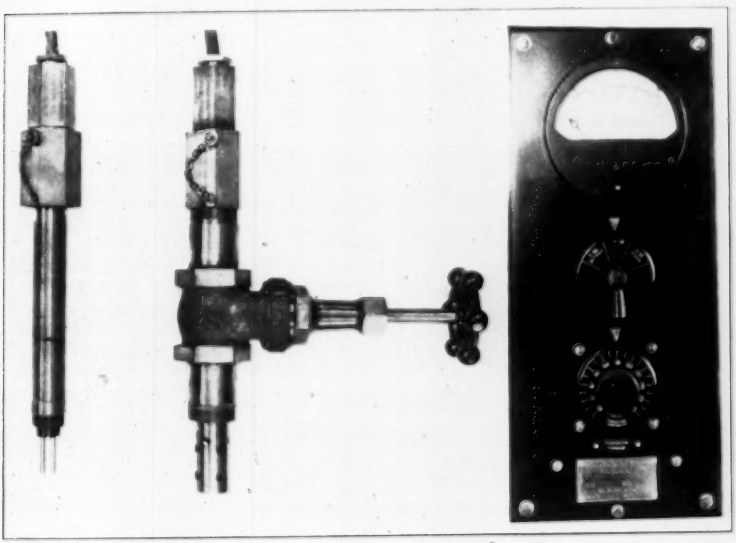
Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional information.

New Salinity-Indicator System

(Sperry Gyroscope Company, Inc.)

THE operation of the Sperry Salinity-Indicator System is based on the principle of the increase in electrical conductivity of water that takes place with the increase of electrolytic impurities, or, conversely, the increase in electrical resistance with the decrease of electrolytic impurities. By immersing two electrodes in the boiler-feed water, a fixed resistance is secured when voltage is impressed upon the system, provided the impurity content and the temperature of the water remain the same. This resistance is read on an ammeter-type indicator on a scale graduated in "Grains of Chlorine per Gallon," the accepted arbitrary scale for salinity indication. If the saline content of the water increases, as in the case of leakage of sea water into the fresh water system, the conductivity between the electrodes increases, and the indicator pointer moves upward in proportion, warning the ship's personnel so that action may be taken before a dangerous condition is reached.

Each conductivity cell is a unit in itself—immersed in the boiler-feed or other fresh water supply and electrically connected to a panel from which salinity indications may be read on an ammeter-type indicator in "Grains of Chlorine per Gallon." The cell consists of two electrodes enclosed in a tubular brass housing fitted with a gate-valve so that the cell itself may be withdrawn for cleaning or inspection. The electrodes are capped with platinum and are protected from injury by a cylindrical guard. Electrical connection is made at the rear of the cell element where the electrodes protrude from the bakelite insulator which supports them.



(At left) Conductivity Cell removed from gate valve showing guard removed. (Center) Conductivity Cell and Gate Valve. (At right) Salinity Indicator Panel.

Two types of indicators are supplied, both being graduated in "Grains of Chlorine per Gallon" and both having a range of from zero to 10 grains. Each type of indicator, however, is supplied in two different styles, the difference being in the width of colored zones.

Type D-1 Indicator is being used for indicating the salinity in the main and auxiliary condensers.

Type D-2 is usually used in connection with the evaporator plant and the fresh water discharge.

Two indicating units are mounted on each panel, each unit being provided with:

a. A voltage-regulator transformer (to prevent the meter readings from being affected by fluctuations in the ship's supply voltage).

b. A temperature compensator (to insure correct meter readings in spite of changes in temperature of the feed water).

c. A double-throw, rotary selector switch (so that readings from either of two conductivity cells may be taken on one indicator).

The transformer—mounted on the back of the panel—has a primary and secondary, and two auxiliary windings. It receives the ship's single-phase 60-cycle supply at nominal voltage of 120, and transforms and regulates it to a constant voltage of approximately 70 volts. There are no contacts or moving parts, and no care or attention is required.

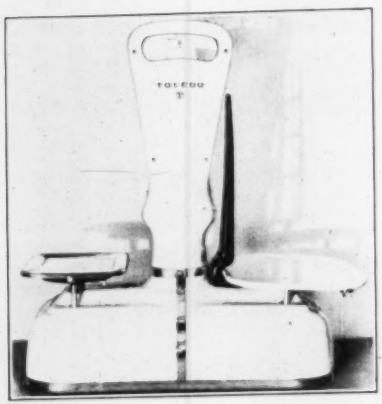
A rheostat shunted across the indicator meter terminals is used with each indicating unit to compensate for change of temperature of the feed water. The rheostat is controlled from the front of the panel by turning a handle, which moves a dial graduated in 5-degree steps from 60 to 160 degrees Fahrenheit, the temperature settings being read with reference to a stationary pointer. As the temperature of the feed water increases, its resistance decreases, causing an increase in current flow through the meter which consequently gives too high an indication. Turning the compensator handle clockwise to a position corresponding to the temperature of the feed water decreases the rheostat resistance, thus causing the excess current to flow through the rheostat instead of the meter, and correcting the meter indication.

The selector switch is a double-pole, double-throw switch of the multi-plate, rotary type. With the switch handle in the vertical or "Off" position the circuits are disconnected. Turning the handle to the left or right connects either one or the other of the two conductivity cells to its meter.

Salinity indicator readings will be more accurate if the switch is not left in the "Off" position. Normal current flowing in the electrical circuits keeps them at approximately the operating temperature at which the equipment was calibrated. Readings taken with the electrical circuits will be slightly higher than the true values.

New Highly Sensitive Scale

A new automatic scale, known as the Gravitygram, not the least interesting feature of which is that it is virtually foolproof against both overweight and underweight, is announced by the Toledo Scale Company. The chart of this instrument shows simply a line marked "O", flanked on one side by the word "under," and on the other by the word "over." There are two platforms, one to hold the article to be weighed, the other to carry the check weights.



Upon the latter platform the operator places whatever weight he wishes his finished article or package to reach, say five pounds. He then "sifts" or feeds in enough of the article being weighed so that the indicator comes to rest upon the zero line.

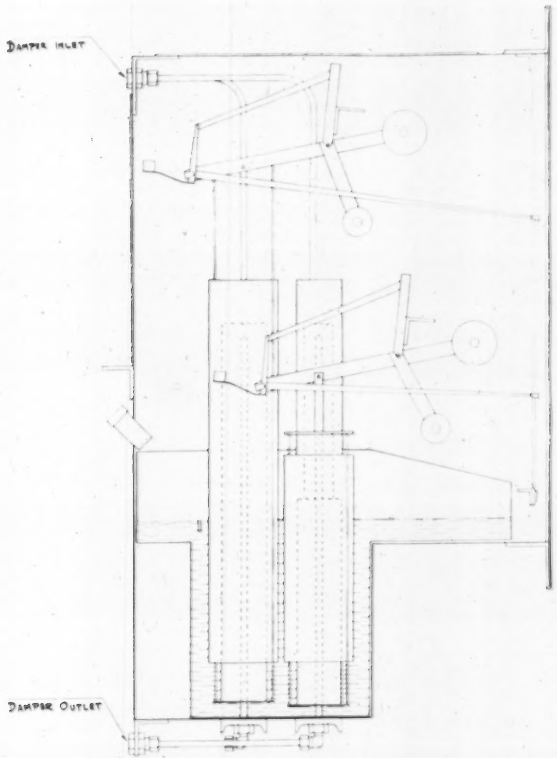
Sensitive to $\frac{1}{64}$ oz., this scale weighs accurately and instantaneously even when out of level. It is not necessary to center the weights or commodity on their respective platforms; wherever they are placed the result is precise. This is a great advantage because it permits great speed with no sacrifice of accuracy in results. Errors in reading simply cannot be made on this scale. The finish is of durable gray baked enamel. The frame is of rigid cast iron. Exposed metal parts are chromium and stainless steel. Scoops, plates and special commodity receivers are available for unusual requirements and the scale is said to be adaptable for any purpose where accurate and rapid check weights are needed in packaging work.

New Pointer Draft Gage Straight-Line Movement

(Ellison Draft Gage Company)

THE new tandem system is designed for zoned air flow control under large forced draft stokers.

To obtain adequate control of the combustion process, the windbox under each retort of an underfeed stoker is divided into from two to four zones fitted with individual dampers through which the air flow may be measured and regulated. Likewise the windbox under the extension grate is divided into several sections—usually the width of two or three retorts. The gages indicating the air flow through the damper and the damper control rods are mounted on a vertical panel so grouped into zones as to facilitate easy damper adjustment to maintain a desired or predetermined air flow to any zone or retort.



To provide a compact gage with minimum space requirement, a tandem arrangement of differential elements has been devised. Standard movements as furnished in the Ellison pointer draft gage straight-line movement are arranged in pairs with two rows of pointers in the unit, one above the other in the same casing, and with the bells one in back of the other in the same oil pan. Scale centers are 2¾" or an equivalent space requirement of 1⅜" width for each reading.

A minimum of height is required with this arrangement since seal provision for maximum static pressures of lower forward row of elements likewise serves the upper row as well.

Extension type differential elements projecting above the beam are provided, affording protection against high induced draft statics. Depth of drop leg is dependent only on maximum forced draft static for which gage is to be sealed.

The double row of pointers readily divides into zone grouping i.e.: top row to show forward zone of all retorts, bottom row the lower zones, etc. To indicate the division between the extension grate and the retort zones, the blinder between these scales is finished in black, all the other blinders in aluminum.

To obtain air flow reading, the pressure drop across the Venturi damper is measured by a standard differential element. This element consists of a movable bell within a stationary bell sealed at the bottom in mineral oil.

Pressure at the damper inlet is piped into the top of the stationary bell and the damper outlet pressure to the draft tube of the inner bell. Thus the movable bell is actuated by the net or differential pressure. The resultant movement is transmitted to the indicating pointer by means of an extension plate on bottom of the moving bell and supporting rods, outside of the fixed bell, to the knife edge bearing on the beam.

All bells are served by a common oil pan or reservoir, provided with oil filler in back of gage through which oil level may be seen on a marker. Drain is provided on bottom of pan and piped through the supporting plate in back of the casing.

Pressure connections are also supported on the back of the casing with fittings tapped ⅛" I.P.T. for connecting pipe lines. Shut-off cocks are furnished for each pipe line.

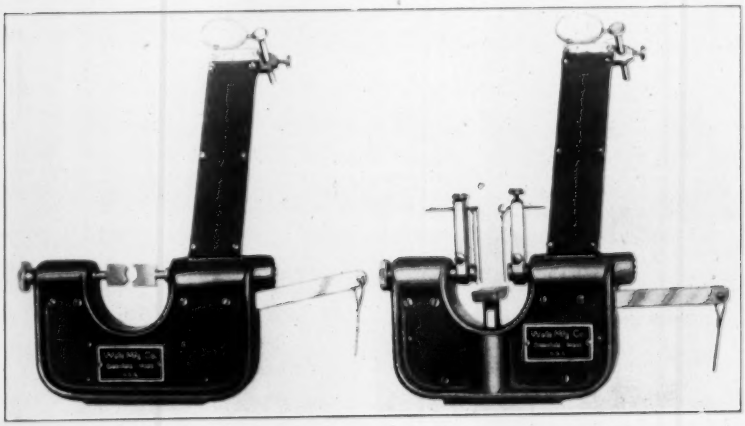
The usual range required is plus 1" of water differential, sealed as specified for maximum induced and forced draft statics. Scale for each pointer is 8" long, the two scales for each pair of pointers being combined in one piece. Scales may be furnished in square root graduations for direct indication of relative air flow, in uniformly spaced graduations, or graduated only at zero and full range as specified.

Movable markers consisting of a metal strip ⅛" wide across the scale are provided for adjusting pressure curves on the scales. They serve as guides for the stoker operator to maintain correct air flow for any given rating or operating condition.

Rapid Inspection Gage

(*Wells Mfg. Co.*)

THE "Wells" Gage is for mass production. The reading is done with the eye and is magnified over 2300 times. To measure screws or taps, anvils or three wire system can be used. The pressure is the same all of the time.



The anvils produce the same results as the tapped hole. This method is fine for three-fluted taps. The anvils are opened by the foot and closed by a spring which insures the same measurement every time. This cannot be obtained by hand pressure. By using flat anvils, round or flat pieces can be inspected very rapidly. The three-wire system is the best and most accurate method of measuring. The wires are held in place for very fast inspection. The wires are adjustable so one gets the wear the full length. They are held loose, yet in the right position all of the time. The gage is set by the use of a standard plug.

New Automatic Oscillograph

(Westinghouse Elec. & Mfg. Co.)

FOR use in recording fluctuations of electric power or mechanical changes translatable into electrical ones the Type PA Automatic Power Oscillograph has been developed.

Although designed primarily for recording automatically all chance disturbances on power systems, the PA oscillograph is adaptable also to staged tests of all kinds. In research laboratories, steam-turbine shops, testing laboratories, college laboratories, and other places where it is desirable to record electrical and mechanical phenomena, applications for this apparatus are found.

The oscillograph consists essentially of four different kinds of galvanometers each of which is designed for recording certain types of phenomena, two low energy incandescent lamps from which light strikes the mirrors on the moving elements of the galvanometers, a moving photographic film upon which the light reflected from the mirrors makes a record of the fluctuations actuating the galvanometers, and a motor geared to the film holder and providing the motion of the film. A six volt battery operates the oscillograph, supplying power for both the lamps and the motor.

The PA oscillograph is protected by an oblong Micarta case, on the sides of which are mounted panel boards providing control for the operation of the device. By means of different panel combinations, the oscillograph is adjusted to record voltage, current, instantaneous and average value polyphase and single phase watts, positive and negative phase sequence current and voltage, and phase angles.

On one end of the case the complete film unit, including the motor, is mounted. The film holder takes a film five inches in width and up to ten feet in length. The motor drives the film through gearing providing speeds of 4.5 and 9 feet per second.

The oscillograph automatically starts to operate within ½ to 1 cycle of a 60 cycle wave after the appearance of a fault.

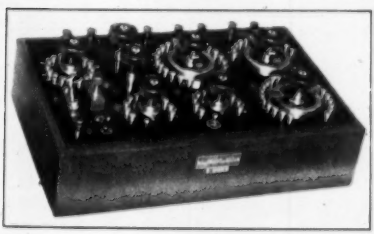
Precision Potentiometer

A PRECISION potentiometer of maximum sensitivity and accuracy has been announced by the General Electric Company. Designed for laboratory use in electric measurements, the instrument reads from one microvolt to 2.1 volts; and, by use of a volt multiplier, to 21, 105 or 1050 volts. Shunts are avilable for measuring currents of from 0.1 to 500 amp. and special shunts for values less than 0.1 amp. can be supplied.

Among the advantages of the instrument are:

(1) A precision of reading to one microvolt may be obtained without interpolation of the galvanometer reading;

(2) Balance against the standard cell is made without changing the position of the ratio plug; and



(3) Readings are taken from the position of the dial switches.

The potentiometer is in a walnut case measuring 17¾ by 11 by 7 inches, and weighs 22 lbs. All switches, coils, wiring, etc. are attached to the black molded top. At the back of the panel are the various binding posts for storage battery, standard cell, the e.m.f. to be measured, and the galvanometer.

On the central and right-hand portions of the panel are five main dials for taking readings. To the left are two rheostats for controlling potentiometer current in balancing it

against the e.m.f. of the standard cell. Below this is the ratio plug to permit the dial switches to be read directly, or to 1/10th indicated value.

In the lower left corner is a key so arranged that, when it is pressed part way down, the galvanometer circuit is closed through a 100,000-ohm resistance to reduce the deflection of the galvanometer. A lock is provided to hold the key in this position if desired. When the key is depressed all the way, this series resistance is short-circuited, and full deflection of the galvanometer is obtained.

Beside this key is a switch for connecting either the standard cell or the unknown e.m.f. in circuit with the galvanometer. Near the upper left corner of the panel is the standard-cell dial which makes it possible to set the potentiometer for the value of a standard cell having an e.m.f. of from 1.0175 to 1.0190 volts inclusive, in steps of 0.0001 volt.

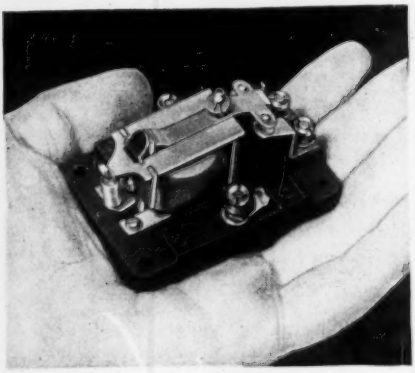
The coils are made of selected manganin wire, wound on insulated brass spools. These coils are aged at least a year before assembling in the potentiometer, eliminating most of the drift which usually occurs.

The accuracy of adjustment of the coils is such that when reading one volt or more, the error is less than 0.005% if the current has been balanced against the standard cell by means of the main dials. If the balance has been obtained by means of the standard cell switch, the error will be less than 0.01% of the readings when both errors are included.

A d'Arsonval galvanometer of suitable characteristics should be used, according to the work that is to be done. Portable galvanometers may be used if a high degree of sensitivity is not necessary.

Dunco Mid-Gett Relays

(Struthers-Dunn, Inc.)



THE new Dunco line of miniature relays, made in eight contact arrangements, are on standard bases, measure $1\frac{7}{8}$" x $2\frac{3}{4}$", and follow in detail the design of regular type Dunco Relays, having the three-legged stool principle of construction, form-wound, moisture-proof coils, renewable contacts, accessible terminals, with moulded bases having a high di-electric.

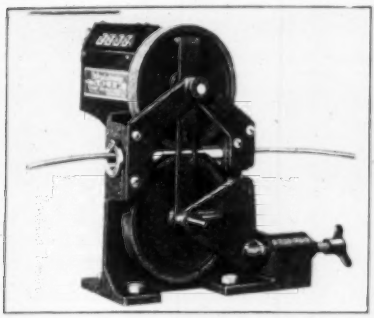
They operate on from 6 to 120 volts A.C., or 24 volts, D.C., depending upon the coil used.

The Meriam Company, Cleveland, Ohio, manufacturers of flow meters, have appointed Anderson Engineering Company, 42 Church Street, New Haven, Connecticut, Leonard Maleson Company, 815 Locust Street, Philadelphia, Pennsylvania, and S. D. Shook & Company, 528 Duquesne Way, Pitsburgh, Pennsylvania, as exclusive representatives in their respective territories.

The Ellison Draft Gage Company of Chicago announce the appointment of the Hauer Power Equipment Company, Union Trust Building, Cincinnati, as exclusive representative in the Cincinnati and southwestern Ohio territory.

Automatic Brake Featured on New Wire Meter

AN entirely new principle of design and construction in a wire measuring machine has been developed and perfected by the Durant Manufacturing Company. This new wire measuring meter features an automatic brake which has proven itself practical and absolutely accurate in a series of tests under working conditions. The braking is accomplished by means of a sturdy spring, the tension of which is adjustable to accommodate various thicknesses of wire. The leather brake shoe can be replaced quickly and easily.



Measuring wheels can be furnished with a straight milled surface, a cross knurled surface or a composition rubber surface for accommodating different types of material to be measured. These wheels, like the entire frame, are made of heavy cast iron and run on a bearing surface equipped with oilers. Wear is practically eliminated.

The frame, brackets and counting mechanism case of this new Productimeter are finished in a new baked black enamel which has an attractive crinkled surface and which is impervious to moisture and the resulting rust.

This measuring meter can be furnished with the counter facing front, back or to the side of the measuring device operating in either clockwise or anti-clockwise rotation. This makes the machine practical for mounting and measuring under practically any condition.

This Productimeter operates at a speed of from 400 to 600 feet per minute depending on the style required and measures wire or other similar materials of from .005 to one-half inch thickness.

Manufacturers of wire, rope, cable, cord, trimming and small leather belting — wholesale electrical supply distributors and jobbers — hardware distributors — contractor dealers, all will find important uses for this new wire measuring meter.

Pulsation Shock Absorber

(*Meriam Co.*)

THE new improved, all welded pulsation shock absorber is claimed to be a simple, yet effective, device for eliminating the unsteady reading so often met with where pressure or vacuum gages are connected to pipe lines carrying gases or liquids having a pulsating flow. The pulsation is particularly objectionable where the liquid sets up "hammer action," and it is seldom practical to install large air receivers on each pipe line.

The trouble may be cured, however, by placing a pulsation absorber in the small line leading to the gage. The pulsating pressure from the line is forced to reach the gage through fine tubing within the compressor air chamber of the gage. This "air receiver" action, combined with the friction of the fluid in the tubing, absorbs the fluctuations from the gage line pressure and gives the true line pressure.

The pulsation shock absorber is only 7" high, there are no moving parts, and all joints are welded to prevent leakage. These absorbers are designed for line pressures up to 10,000 lbs.

Directional Gyro

(Sperry Gyroscope Co., Inc.)

THE directional gyro is an airplane navigating instrument for indicating to the pilot the compass course of his p'ane. It has no meridian seeking properties and therefore must be occasionally checked and re-set in accordance with the heading as given by the magnetic compass. Unlike the magnetic compass it does not oscillate on turns or in rough air.

If used in connection with the Sperry horizon, the directional gyro allows a pilot to perform all essential maneuvers without exterior visibility. It can also be used as an extremely accurate index of turn for flight purposes.

The determination and maintenance of the heading of an airplane has always been one of the most difficult problems of flying. Due to the low directive force of the earth's field, the magnetic compass can only be relied upon when the airplane is steady in the air, not only directionally but also with respect to disturbances produced by rough air.

In general, the practice with the magnetic compass is to steady the airplane near the desired compass heading, wait until the compass card has come to rest, and then attempt to correct for any discrepancy. This procedure involves exterior marks or the use of some gyroscopic turn index; for magnetic compass oscillations will not dampen out as long as the airplane is moving in azimuth.

If the magnetic compass could be held on its azimuth without swinging or oscillation, the problem would be simple, and a desired course could be picked up and maintained simply by keeping the lubber line opposite the desired heading. For all practical purposes, the directional gyro allows this method of course keeping and flying to be employed. It therefore combines the most desirable qualities of both a flight and a navigational instrument.

In appearance, the directional gyro resembles a vertical card magnetic compass intended for instrument board mounting. It consists of a case with a round window, through which a compass card may be seen. The window is mounted flush with the instrument board, and directly below it is located a setting knob. The card appears at the top of the window, so that when mounted directly below the Sperry horizon, the eye will have the shortest distance to travel between the two instruments.

Inside the case, and encircled by the card, is an air driven gyroscope with its axis horizontal, operated by suction from a venturi. It is supported in gimbals so that the airplane may turn freely around it in azimuth. Sufficient angular freedom is available in other directions so that the gyro may remain horizontal irrespective of normal bank or pitch variations of the plane.

When the setting knob referred to above is pushed in, it engages a gear on the azimuth circle and at the same time cages the gyro and holds it horizontal. Turning the knob will turn the compass card until it indicates the desired compass course. When the setting knob is released the gyroscope remains with its azimuth in the position at which it was set.

With the airplane in flight, the magnetic compass is steadied until it has ceased oscillating on any arbitrary reading of the directional gyro. The setting knob is then used to make the directional gyro correspond to the desired magnetic compass course or known geographical heading.

In practice it is to be used exactly as a compass which rough air and violent turns cannot affect in any way whatsoever. The directional gyro will maintain any setting with an accuracy of within three degrees of arc in fifteen minutes of time. At approximately fifteen minutes to one-half hour intervals it should be checked against the compass and reset if it has drifted off.

Direct Reading Time Meter

THE actual total operating time of any electric equipment using alternating current is shown by a time meter introduced by the General Electric Company. Within the meter is a synchronous motor, like that used in a G. E. Telechron clock, which operates while the circuit of the equipment is closed. This motor, through suitable gearing, drives a cyclometer five-digit counter, arranged to read in either hours or minutes.

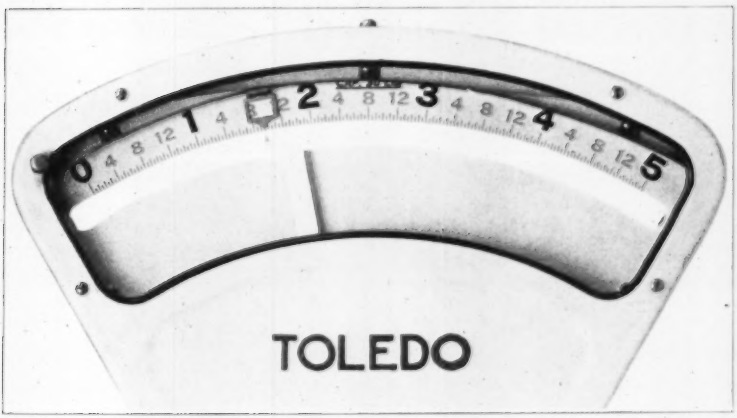
Such a meter is especially valuable in checking piece-rate operation, particularly when idle-time credit is allowed in computing wages. A weekly reading of the meter shows how many hours the machine was in operation, and hence, by deduction, the number of idle hours.

Other applications to which the meter has been applied include checking on the amount of time electric refrigerator mechanisms are in operation, and in making life tests of radio and other tubes, incandescent lamps, etc.

The meter is supplied on a pedestal for portable use, or with a threaded connection for permanent mounting on conduit. The meters are available for 110, 220 or 440 volts, and for 25, 50 or 60 cycles; but no one device has more than one voltage or frequency rating.

New Indicator Speeds Packing

(Toledo Scale Company)



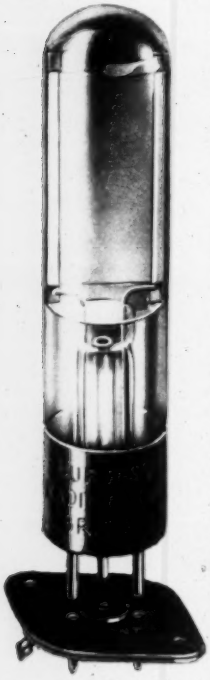
THE hand set indicator speeds up predetermined weighing operations. This indicator is set at the desired mark on the pound and ounce chart. As the scale hand approaches the desired weight, it is easy to ascertain at just what point the filling operation should cease.

This indicator was designed primarily for use on the Computagram. It is flush with the scale hand, which gives finer accuracy. It is easily and quickly moved to any position on the scale chart. With this indicator attachment, it is possible to transform this straight weighing Toledo Scale into a double utility scale for packaging predetermined quantities. It may be used in any packaging or filling operation where exact weight is essential.

New Light-Sensitive Cell

(Burgess Battery Company)

MUCH has been written and said in recent years regarding light-sensitive or photo-electric cells. Wonderful things have been predicted through their use in industry. Yet until now the commercial application of light-sensitive cells has been decidedly limited and quite disappointing, due to the limited amount of current that could be passed through cells so far available, to their low degree of light sensitivity, and to the elaborate and costly associated apparatus. An entirely new development along these lines, however, now promises to overcome the previous limitations and to open up an almost unlimited industrial field for the light-sensitive cell.



Known as the Burgess Radiovisor Bridge, the new light-sensitive cell represents the original development work of British scientists, followed by the ingenious applications by German technicians, and finally the adaptation of the cell and its circuits to American practice by our own engineers.

The new cell or bridge consists of a tall glass tube with a three-prong base. Inside the bulb is a flat plate occupying the center and supported by two heavy lead-in wires. The plate is of glass upon the front side of which are two interlocking comb-like electrodes of gold, fused in place. These electrodes are covered over by a thin layer of selenium-like enamel, the conductivity of which changes with the amount of light falling on it, thereby providing a light-sensitive cell. Due to the considerable amount of current that can be passed through this cell as contrasted with the minute current passed by the usual photo-electric cell, it becomes possible to utilize simple, practical and inexpensive circuits, thereby multiplying the possibilities of light control. In fact, the cell can operate a relay direct, for controlling a circuit handling a few watts of energy, while a second relay provided with a novel form of vacuum contact permits of handling several hundred watts for serious work. For more intricate applications, vacuum tubes can be employed, in which event considerably less amplification is required than in the case of the usual photo-electric cell, due to the higher initial current available.

The bridge possesses a high ratio of dark resistance to resistance when subjected to an illumination of 10 foot candles, and is practically independent of voltage. The bridges can be used at various voltages, but for convenience they are tested at the factory at only one value, which value is stated when the bridge resistance is given. The bridges are available in D.C. and the A.C. types.

Extreme ruggedness characterizes the new light-sensitive cell. It is unaffected by vibration or rough handling. Each bridge has a maximum wattage rating of .01 watt in.^{2} of sensitive surface, the surface of the standard bridge being 1.5 in.^{2} For greatest sensitivity, the entire active surface should be employed, rather than just a portion. If a sharp beam of light is being employed for light control, a suitable optical system should be introduced so as to spread the light over the entire surface of the bridge. The life of the bridge is almost unlimited, since no measurable deterioration occurs with age whether on current or not.

In the case of the D.C. bridges, it is necessary to observe the polarity, since the cells have been aged and rated on the basis of the indicated polarity. A change in resistance will occur if the polarity is reversed.

As already stated, the light-sensitive surface of the bridge consists of an enamel or coating derived from selenium. The coating is carefully prepared, applied, heat-treated and aged. While the light-sensitive properties of the element selenium have been known for several decades, the many attempts to apply it to light-sensitive cells have left much to be desired. It has remained for British scientists to develop an entirely new form of selenium cell in which the active material is spread on a glass plate carrying the interlocked gold electrodes, in the form of a film of almost infinitesimal thickness, followed by precise heat treatment for proper annealing. The thin layer of light-sensitive material makes possible the employing of the entire mass for useful purposes, thereby minimizing any useless shunt resistance which might reduce the sensitivity of the bridge. The result is a cell that handles several times as much current as the usual photo-electric cell, that is highly responsive to light variations as proven by its practical application in sound motion picture reproduction, that does not fatigue in

continuous use, and that does not deteriorate even after long service.

Various basic circuits, together with the associated equipment, have been evolved by the Burgess engineering staff, in keeping with American practice. A polarized relay is being developed for operation directly off the bridge, in conjunction with a "B" battery. The relay will handle several watts of energy for light work. If real power must be handled, there is a telephone type relay provided.

In Great Britain and Germany, the bridge and associated equipment have been aplied to burglar alarms, fire alarms, street lighting control, motor car parking lights, fog detectors, automatic counting, color matching, railway stop systems, and other purposes. It remains for the inventive genius of American engineers and experimenters to put these imported tools to work in bringing about a practical light-control era which will simplify many tasks in industrial, social and community life.

New Micrometer Microscope

(R. Y. Ferner Company)

THIS microscope is known as model 281-D. It may be used for checking the profiles of small gears or screw threads, or for measurements of fine wires, textile fibers, diamond dies, jewel bearings, dies for the manufacture of rayon, and similar articles.

The micrometer of this instrument is of a highly improved type. The screw is made of a special heat treated steel and is cut and checked with the highest precision. It is fitted and lapped in its bronze nut. The thrust bearing of the screw is a sapphire ground optically flat to eliminate periodic error and insure accurate working of the screw. A counter-acting spring eliminates any play that would be prejudicial to the precision of the measurements.

In the micrometer drum a new white material is used for the graduated surface. This has a matt finish which makes the reading of the drum an easy matter, free from eye strain. The drum is very accurately graduated on a circular dividing machine which is another factor in the high precision of its readings. A large milled drum serves to make sensitive settings of the head a simple operation. The divisions are so fine that accurate estimates of tenths of a division can be readily made, a tenth of a division being 0.000005" on the instruments graduated in inches or 0.0001 mm. on metric microscopes. A glass turn counter in the field of the eyepiece is so graduated that to obtain the complete reading it is merely necessary to set down successively the numbers indicated on the turn counter and the micrometer head. An adjusting screw is provided by which the graduations of the turn counter can be set to agree with the cross wires of the reticle when the micrometer head is set to zero. The reticle consists of parallel spider threads.

An unusual mounting of the eyepiece is provided in that it is on a small carriage which slides in the top of the micrometer box under action of a rack and pinion. This permits placing the eyepiece over the center of the part of the field in which the measurements are made, to further reduce any distortion of the image which is primarily corrected by the achromatic lenses of the eyepiece. The focusing of the eyepiece is rendered easy by use of a spiral groove in the fitting and a pin working in it so that an accurate focusing may be had readily by an easy rotation of the ocular.

The microscope tube just below the micrometer box is fitted with a collar cut accurately to the right length to give the exact screw value of .005 inch or 0.1 mm. per revolution and makes it possible to dismantle the microscope without danger of losing the original calibration.

Below this collar a focusing ring having a fine screw thread is supplied, by which the whole microscope can be raised and lowered in its support to focus it properly on the object sighted upon. This adjustment, when made, can then be locked.

Just above the objective a prismatic illuminating device is built into the microscope. Illumination is furnished by a miniature Osram lamp of 4.5 volts mounted in a tubular holder attached to the microscope tube and fully adjustable. A green monochromatic filter is used in front of the lamp to further reduce eye strain and give higher resolving power.

The objective, of the double type, is made by the famous lens maker, Koritska, and is specially designed for metrological use, having a large numerical aperture with resulting high resolving power. In the microscope 281-D it has a magnification of 5×, which, with the magnification of 8.3× of the eyepiece, gives a total magnification of 41.5× for the instrument. The working distance of the objective is 20 mm. In another more precise microscope, No. 286-D, the objective has a magnification of 7.5× giving a total magnification of 63×. In this instrument one division of the micrometer head is only 0.00002" or 0.0005 mm.

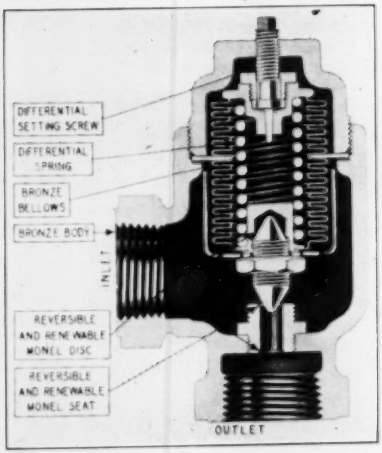
A third microscope, of still higher accuracy, designated as No. 287-D, and having a total magnification of 96×, is also available, and is used primarily for the most elaborate comparators such as for geodetic base bar measurements or transverse or longitudinal comparators for standardization and calibration of the most precise length standards, such as reference and working standard yard and meter bars. This microscope reads to 0.00001" or 0.00025 mm. per division or accurate estimates may be made to a millionth of an inch or a fortieth of a micron.

The stand for microscope 281-D shown in the illustration is of very rigid construction, and makes a reliable and handy apparatus for the checking of small manufactured parts. The table is $2\frac{3}{4}$" in diameter and there is a working distance of $3\frac{7}{16}$ inches from the center of the table to the edge of the supporting arm. The table is of a special cast iron.

New Steam Trap

(C. J. Tagliabue Mfg. Co.)

THERE are several outstanding features of this new steam trap, that emphasize its unusual economy in operation. The new and exclusive differential setting feature makes it possible for the TAG steam trap to discharge condensate at a temperature corresponding to a uniform differential pressure from 0 to 20 lbs. below the operating steam pressure. If the trap is set to discharge condensate at a temperature corresponding to as much as 20 lbs. less than the operating steam pressure, it will discharge the condensate at this differential regardless of whether the steam pressure is 50 lbs., 75 lbs., or 125 lbs., and without any further adjustment of the differential setting.



When the differential setting screw is all the way up on the TAG trap, there is no tension on the spring and the trap will discharge condensate from 1 to 2° below the temperature of the operating steam. When tension on the spring is applied, by simply turning down the setting screw, a mechanical pressure is created on the inside of the skillfully designed bronze bellows which aids the vapor pressure developed in the bellows to close the valve. Thus the amount of mechanical pressure exerted by the spring determines whether the trap will close at the temperature of the operating steam or 5, 15, or 25° below this temperature. And, in reverse effect, whether it will open to discharge condensate at 1 to 2° below the operating temperature of the steam or at 7, 17, or 27° below that temperature.

There are other outstanding advantages offered in the TAG steam trap, the makers aver, there are, for instance, reversible as well as renewable Monel seats and discs—two for one in every TAG trap. Simply by unscrewing and reversing the seat the outlet end becomes a new seat. Merely by inverting the disc, the reverse, extra disc is brought into play.

The company has concentrated on one size—1" only, as the full $\frac{5}{16}$" valve opening assures ample capacity and permits of easy interchangeability on every steam line. Thus only one set of replacement parts is required for any application within the capacity of the TAG trap.

Micrometer Water Level and Pressure Gage

(C. F. Casella & Co., Ltd.)

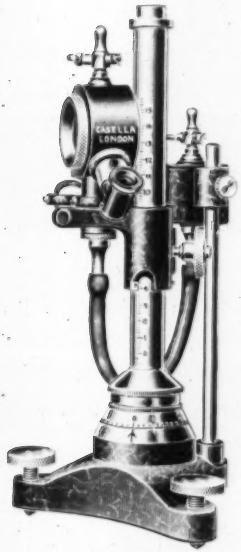


Fig. 1

THE instrument illustrated herewith was produced with the object of providing a gage, the accuracy of which can be relied on to within $\pm^1/_{200}$ in. head of water and which is capable of being used for all pressures likely to be encountered in normal practice or for taking levels to a degree of refinement hitherto impossible. The gage has already been used for the measurement of pressures in gas mains and flues, air flow in wind channels—in connection with suitable Pitot tubes—and pressures given by blowers and ventilating fans. In addition to uses of this kind the instrument can be employed very simply to measure the depth of water in tanks, for example, during engine tests, or to determine the daily or hourly evaporation from large water surfaces, such as tanks, lakes or reservoirs. A small modification of the apparatus enables it to be used for taking the levels of foundations, shafting, rails, or for any similar purpose requiring an accuracy of the order stated above. It can also be used to determine the deflection of bridges, floors, or any structure under a static load. Fig. 1 illustrates an instrument arranged to measure up to 36 in. head. This form is fitted with a standard scale and vernier. Fig. 2 shows a smaller instrument having a range of 0 mm. to 150 mm. fitted with a standard scale and micrometer drum, which is divided to $^1/_{10}$ mm. As the precision with which the reading point can be set exceeds any of the ordinary requirements the final accuracy depends solely on the value of the divided scale and vernier used to read off the differences in head of water.

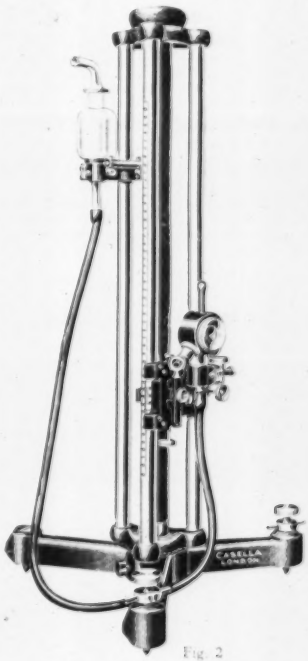


Fig. 2

To use the instrument shown in Fig. 2 it is first set up level by means of the two levelling screws fitted to the base and the circular bubble on the top of the column. The index of the measuring chamber is then brought to the zero of the scale on the column by means of the milled head and the centre of the cistern approximately level with the measuring point of the chamber. Water is now poured into the cistern until it rises just above the point in the measuring chamber. On looking into the eyepiece and adjusting the illuminating mirror the point and its reflected image, greatly magnified, will be seen as shown at Fig. 3. This result is caused by the fact that the undersurface of the water acts as a totally reflecting plane mirror with the consequence that a very perfect definition of the measuring point is obtained. If the measuring chamber is raised or lowered by means of the micrometer drum the point can be brought to touch its reflection or, in other words, to the exact level of the surface of the water. The divided ring of the micrometer drum can then be turned round on its independent fitting to bring the zero mark opposite the fixed line on the base. The instrument is now set to zero and is ready for taking measurements.

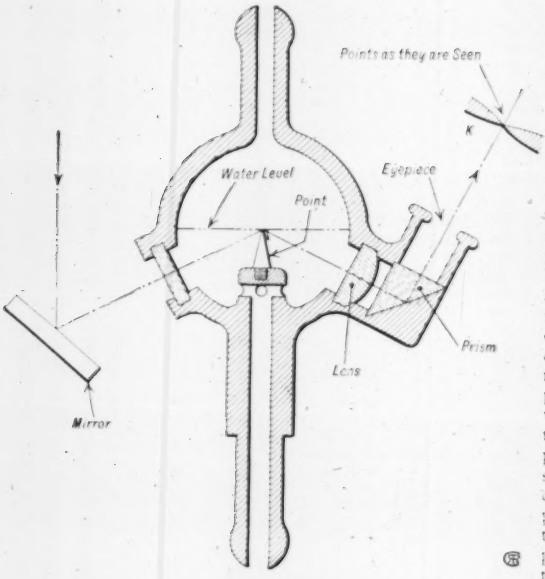


Fig. 3

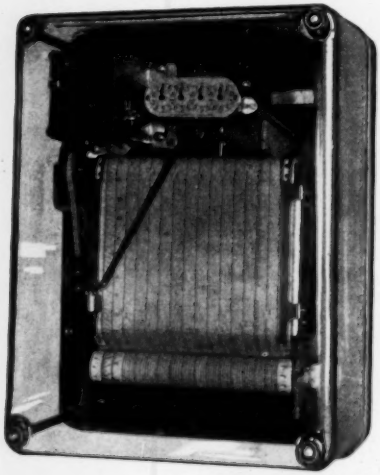
To measure a pressure of 100 mm. of water the measuring chamber is moved up the column by means of the milled head until its index is opposite the 100 mm. division on the scale. If the pressure to be measured is now connected to the tap on top of the cistern the water will rise in the measuring chamber approximately to the point. This chamber can then be adjusted up or down by means of the micrometer drum until exact coincidence of the point and its image is secured. The pressure in head of water will then be the reading of the scale, i.e.; 100 mm plus or minus the amount shown by the micrometer drum. If a difference in pressure or a vacuum is to be measured the lower pressure is connected to the tap on the measuring chamber.

New Recording Demand Watthour Meter

(*Westinghouse Elec. & Mfg. Co.*)

THE Type RB recording-demand watthour meter indicates on a four counter dial the total kilowatt-hours consumed, and records on a chart the integrated demand in kilowatts over successive, predetermined intervals.

This meter consists of a watthour meter register containing gears for driving the four integrating counters and causing the pen to advance across the chart a distance proportional to the kilowatt-hours consumed during the interval for which the meter is set. At the end of this interval, the pen is automatically released from the driving mechanism and swings back to the zero position where it is again meshed with the gear train ready to advance during the next interval. Just before the pen is released from its maximum position, the record paper is advanced a fraction of an inch, assuring a distinct record of maximum pen travel.



In this manner, a record of kilowatt demand taken at periods of desired length (usually between 5 and 60 minutes) is obtained.

A small synchronous motor serves both to determine the time intervals and to furnish power for advancing the chart. During the time-interval, this motor stores energy in a spring which, at the end of the time interval, is released, advancing the chart and resetting the pen to zero.

The complete meter element is fastened to a one-piece, cast-iron frame so that the element may be removed from the base without disturbing the calibration or the relative position of any of the meter's parts. A molded-glass cover makes the appearance particularly suitable for switchboard applications. The meter is relatively small and requires little space for mounting.

It is installed like an ordinary watthour meter because it is entirely self-contained, and requires no additional apparatus or wiring except when used with instrument transformers.

A Machine That Throws Out Bad Beans

ELECTRICITY, already the donor of many useful and helpful gifts to agriculture, has produced a robot servant for the bean growers. This is a bean sorting machine, designed by the firm of Hammerslag and Tinkham of Grand Rapids in association with the General Electric Company, to look over navy beans and throw out all those which do not meet the required standard of whiteness.

Brown or otherwise discolored beans are considered a poor grade of the bean crop, and to sort them from the white ones has always been an expensive and unsatisfactory job. Not only are many such beans actually bad but there is also a psychological prejudice against dark beans. As a result the new machine is expected to be of great value to the industry.

By means of the photo-electric tube, an electric eye which is sensitive to changes in light, the machine inspects the beans one by one as they pass on their way to be packed. As long as white beans pass in review the eye of the machine is unaffected; such beans pass muster and proceed to the packing operation. But the appearance of a dark bean sets up a veritable electronic storm—a relay clicks and a metal finger reaches out, deflects the bean and causes it to drop into a separate container.

In operation, beans to be sorted are fed into a hopper on the machine. Passing under this hopper is a drum with a number of small apertures around its circumference, and with a constant suction drawing air through the holes. Beans are thus picked up by suction and carried around on the edge of the drum. On their way to the sorting eye they pass a mechanical "patter" which adjusts them to the correct position so the electric eye can view them properly.

The viewing chamber in which the electric eye watches the beans is so arranged that intense light falls on each bean as it passes in front of the photo-electric tube. The revolving drum moves in small jumps, pausing a moment between jumps, and thus there is a brief period during which each bean rests in front of the sorting eye without movement, thus preventing any shadows from interfering with the accuracy of the device.

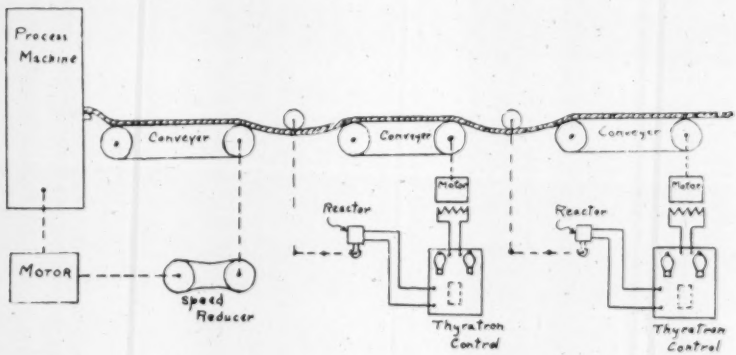
Conditions are normal when a white bean pauses before the photo-electric tube; the bean passes on to be dropped into the receptacle for perfect beans. But when a dark bean stops in front of the sorting eye the normal current passed by this tube is materially diminished. This drop in current affects the output of a pair of amplifier tubes and is used to "trip" a thyratron, thereby allowing it to come into action. The thyratron is likewise a tube but is capable of passing thousands of times as much current as a high vacuum tube. It acts as a relay and by means of a magnet causes the metal finger to flick the bean from its place on the drum and into a chute through which it drops by gravity into a receptacle holding only those beans which were tried and found wanting.

Commercial application of the new device is expected to be made soon by the Electric Sorting Machine Company, a new corporation formed to introduce the machine to the bean sorting industry. A new elevator will be built near the bean district which will house a battery of two hundred of the photo-electric bean sorters. It is estimated that such a quantity of machines will easily sort at least a carload (approximately 40,000 pounds) of beans a day.

Rubber Conveyors are Synchronized by Thyratron Tubes

A CONSIDERABLE reduction in wastage and an important simplification of operation are among the results of the application of Thyratron tubes to the synchronizing of rubber conveyors by the B. F. Goodrich Company. Conveyors are used in much of the processing work in a rubber factory, and it is important that the speeds of the various conveyors in a chain are synchronized.

The speed of the synchronized group is usually determined by the speed of the material entering one conveyor. The speeds have heretofore been controlled manually, but the results were unsatisfactory as a very slight disagreement in speeds might be the cause of a high percentage of waste material.



With the aid of General Electric engineers, the B. F. Goodrich Company was able to install equipment using Thyratron tubes which synchronized the conveyor speeds satisfactorily. The arrangement, which is similar to others made for different applications by the General Electric Company, is as follows:

The first conveyor, or the one receiving the original supply of material, is driven at a fixed rate of speed, depending on the material in question, and the other conveyors are synchronized with this key conveyor. The material, as it passes along, dips slightly between any two conveyors. In each of these dips rides a wheel attached to a balanced lever mechanism. The lever mechanism, at its other end, governs the movement of the core in a reactor. Variations in the reactance of the reactor (governed by the position of the core) control the output voltage of a pair of Thyratrons in the circuit of the motor driving the conveyor whose speed it is desired to govern.

By this arrangement, when a conveyor is running too fast for the preceding one, the slack material between them tightens, the rider wheel rises, the position of the core in the reactor is changed, the Thyratron tubes pass more current and to the motor field the motor slows down. Conversely, when the conveyor is running too slow, the reactor core moves the other way causing the Thyratron tubes to pass more current and the motor speeds up. As a result the tension between conveyors keeps the speeds in synchronism.

New Thermal Converter

(Lincoln Meter Company, Inc.)

THE thermal converter is an electrical instrument in which, by means of thermocouples, a predetermined and accurately adjusted direct current potential is developed by a given quantity of power in an alternating current circuit to which the instrument is connected.

The thermal converter is used for totalizing either remote or local electric system loads.

The direct current circuits of two or more thermal converters may be connected in series. The total direct current E.M.F. that is developed in this series circuit is applied to a Leeds and Northrup potentiometer which records graphically the total load in the systems to which the several thermal converters are connected. The converters may all be connected to a common potentiometer recorder; or, the converters may be divided into groups, and connected to several converters that are in turn connected to a grand total recorder. The converters may be widely separated from each other, and the potentiometer may be at a considerable distance from any or all of the converters.

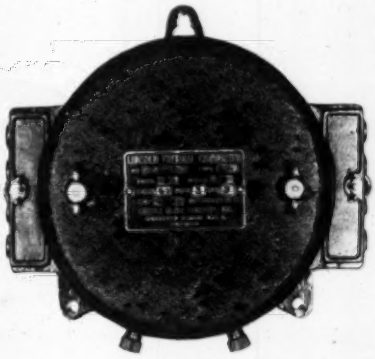


Fig. 1

The thermal converter is constructed so that the direct current E.M.F. developed when 1 kilowatt is applied to the alternating current circuit of the converter will be some definite potential, which may be any value between approximately 5 millivolts and 40 millivolts. Since the millivolt output may be set at any desired amount two or more converters which are connected to the same recording potentiometer do not necessarily have to be connected to instrument transformers of identical ratios. For example, two thermal converters might be used, one of which was connected to a current transformer having a ratio of 200 to 5, and the other to a transformer having a ratio of 100 to 5. By using converters such that the first developed 20 millivolts, D.C. and the other developed 10 millivolts D.C. per kilowatt input, correct totalizing would be obtained.

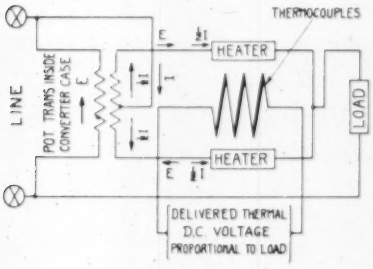


Fig. 2

Fig. 2 is a schematic diagram of a single phase thermal converter. The potential coil of the converter is a transformer whose primary is connected across the line or to potential transformers, and whose secondary winding is connected in series with the heaters as shown in the diagram. Therefore, a low voltage circulating current, which we shall term "E," proportional to the voltage of the line is set up. This is indicated by the arrows marked "E." The line current is connected to the center tap of the low voltage secondary. Since the impedance of the two paths from this center tap to the load is the same, one-half of the line current "I" will take the path through the upper heater in the same direction as the circulating current "E," and one-half of the line current will take the path through the lower heater in the opposite direction to the circulating current "E."

The currents in the upper and lower heaters are $(E+\frac{1}{2}I)$ and $(E-\frac{1}{2}I)$ respectively. The heat generated in the heaters is proportional to the squares of these currents. It can be shown algebraically that the difference in heat between the two heaters is directly proportional to the power in the line to which the converter is connected.

$$(E+\tfrac{1}{2}I)^2 - (E-\tfrac{1}{2}I)^2 =$$
$$(E^2 + EI + \tfrac{1}{4}I^2) - (E^2 - EI + \tfrac{1}{4}I^2) = EI$$

which is proportional to power.

The thermocouples shown in the diagram have one set of junctions adjacent to one heater, and the other set adjacent to the other heater. Therefore, they develop a direct current E.M.F. proportional to the difference in heat between the two heaters, and therefore, in proportion to power.

Since the currents "E" and $^1/_2$ "I" add vectorially, the heating effect which results takes power factor into consideration.

Of course, there are two of these single phase elements in a polyphase converter, with the thermocouple circuits in series feeding the direct current output terminals. The complete thermocouple circuit of a 20 millivolt polyphase converter has about 30 ohms resistance.

Vacuum Thermocouples for Measuring Weak Alternating Currents.

(P. J. Kipp & Zonen)

A SET of vacuum thermocouples in bridge connection is shown in Fig. 1. Vacuum thermocouples a, b, c and d each consist of a strip of constantan and manganin, 1 micron thick, 10 mm long and 0.2 mm wide and G is a galvanometer. The resistances of the thermocouples are in equilibrium in a Wheatstone bridge arrangement. The total resistance is about 25 ohms.

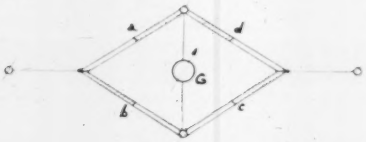


Fig. 1.

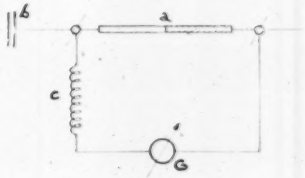


Fig. 2.

An A.C. of 1 milliamp. generates an EMF of 22.5 microvolt and causes a deflection of 50 mm at 1 meter with a Moll galvanometer. Using a galvanometer type Zc one attains a deflection of 500 mm. The 4 thermocouples are protected against outer disturbances by a double walled metal cover. The instrument can be calibrated with direct current and be loaded up to 100 mA. It is supplied in the form illustrated in Fig. 3.

Fig. 2 is the diagram for single vacuum thermocouple. "a" is a vacuum thermocouple (resistance about 25 ohms) of the same metals and dimensions as the couples mentioned above; b is a condenser and c a choke coil.

Fig. 3.

An A.C. of 1 milliamp. generates an EMF of 11 microvolts and causes a deflection of 25 mm at 1 meter with a Moll galvanometer, or of 250 mm with a galvanometer type Zc. The instrument cannot be calibrated with direct current. It can be loaded up to 50 milliamps and is also supplied in the form as shown.

The Moll galvanometer has a resistance of 50 Ohms and a sensitivity of 6×10^{-9} amp. for 1 mm at 1 meter scale distance. The Zc galvanometer has a resistance of 15 Ohms and a sensitivity of about 10^{-10} Amp.

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GAS SERVICE JOURNAL. Vol. V, June, 1931 of this publication contains the following articles: "Performance Curves of Balanced Valve Regulators," "The Ignition Velocity of Gas Mixtures," "Itinerant Inspectors and Traveling Meter Men Guard the Gateways," and "The Newspapers." Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

RELAYS. Two additional pages for the Dunco Relay Catalog, one covering midget relays, the other sequence relays. Struthers Dunn, Inc., 139 North Juniper St., Philadelphia, Pa.

MICROSCOPE RECORD. No. 23, May, 1931 issue of this publication has as its feature articles the following: "Current Microscopy: Notes on Embedding very delicate Plant Tissue" by W. R. Ivimey Cook, "Three Diatoms from Yorkshire" by Rev. Dingley P. Fuge, etc. W. Watson & Sons, Ltd., 313 High Holburn, London, W. C. 1, England.

TEMPERATURE CONTROL. Three circulars entitled: Better furnace operation through better hot blast control; Better glassware through better temperature control; and Better steel parts through better temperature control. These can be identified as Circ. 266-P, Circ. 275-P and Circ. 182-P. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

REGULATORS. Bulletin No. 205 describes and illustrates Type D K M-J-L Regulator for combustion control. Morey & Jones, Ltd., 922 So. Hemlock St., Los Angeles, Calif.

AUTOMATIC REVERSAL. Bulletin No. 841 describes every phase of automatic reversal of open-hearth furnaces, how reversals are made automatically—what the system is—how it operates—and its advantages. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

STIFF-ARM FITTINGS. A new four-page bulletin describing stiff-arm fittings for combustion control, which can be combined and assembled to make up practically any type of connection that may be required. Carrick Engineering Company, 431 S. Dearborn St., Chicago, Ill.

AUTOMATIC FUEL EQUIPMENT. Bulletin A-11 describes and illustrates Type TU safety control and constant current focandescent ignition control for automatic fuel burners. The Mercoid Corporation, 4201 Belmont Avenue, Chicago, Ill.

CONTROLS. A looseleaf catalogue completely describing—pressure or suction regulators, control of an open hearth, gas mixing control, combustion control, pressure convernors, draft control, etc. Shallcross Control Systems Co., 1195 Thirtieth St., Milwaukee, Wis.

BALANCES. Bulletin No. 315 describing specific gravity balance for liquids. Bulletin No. 331 devoted to weights for exacting analytical work. Also a number of brief circulars devoted to micro balances, fractional weights of tantalum, precision balances etc. Christian Becker, 92 Reade St., New York.

INDICATOR. Bulletin 3264 entitled Safeguarding the Gas Compressor by means of the Mathak Indicator. Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh, Pa.

TESTING MACHINES. Circular describing and illustrating universal hydraulic testing machines Type MP-4 and Type P-2. Steel City Testing Laboratory, 8843 Livernois Avenue, Detroit, Mich.

CYCLE CONTACTORS. Bulletin No. 1212 describes many different automatic time cycle contactors used to increase rate of production and reduce spoilage and production costs. Automatic Temperature Control Co. Inc., 34 East Logan St., Philadelphia, Pa.

DRIFT INDICATOR. Circular showing Type 625 drift indicator which is a necessary auxiliary to a compass, if accurate aerial navigation is to be accomplished. Pioneer Instrument Co., 754 Lexington Avenue, Brooklyn, N. Y.

PULSATION ABSORBER. Bulletin No. 2 describes the Pulsation Absorber for pressure gages. The Meriam Co., 1955 W. 112th St., Cleveland, Ohio.

PHOTOELECTRIC METER. Bulletin No. 103 describes and illustrates Type No. 25741 photoelectric meter which is useful for quickly determining the relative color concentration of solutions, turbidity, translucency, etc. Eimer & Amend, 3d Ave at 18th St., New York City.

THE GRAPHIC. No. 531 of this publication is devoted to the portland cement industry. The Esterline Angus Co., Indianapolis, Ind.

VISCOSIMETER. A circular illustrating the Lubri-Guide, a direct-reading automatic viscosimeter for Diesel engines. Viscosity Engineering Corp., 250 West 54th St., New York, N. Y.

SATURATION CONTROL. Bulletin 1034 describes and illustrates saturation control for the rehydration of natural gas, includes reprint of an article on its application, and relative humidity tables. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.

WATER WORKS JOURNAL. Vol. XXIII, June, 1931 contains the following feature articles: Why Dry Years Hold No Terrors for Citizens of the East Bay, Calif., Municipal Utility District; Physiological Effects of Minerals Naturally Occurring in Water, etc. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

WATER STILLS. Bulletin 31 B is one of a series describing automatic water stills, a reliable source capable of producing pure distilled water, when it is needed as it is required. Precision Scientific Co., 1736 N. Springfield Ave., Chicago, Ill.

BALANCES. Circular AD 35 describes two new Cenco balances identified as No. 666 and 651. Central Scientific Company, 460 East Ohio St., Chicago, Ill.

X-RAY. A folder entitled Secrets of Metal, a New X-ray Service to Industry. Claud S. Gordon Co. 708 West Madison St., Chicago, Ill.

LABORATORY PRESS. A circular describing a hydraulic hand-operated powerful laboratory press for quick, accurate small-scale tests. Fred S. Carver, 345 Hudson St., New York, N. Y.

RECORDERS. Leaflets describing the Vibracorder, the Recordograf and the Tachograf used to check on trucks and buses. Ohmer Fare Register Co., Dayton, Ohio.

GAGE BLOCKS AND ACCESSORIES. A broadside showing how practically every commercial measurement of length can be performed, with these gage blocks and accessories. C. E. Johansson, Inc., Division of Ford Motor Co., Detroit, Mich.

FATIGUE MACHINE. Bulletin No. 1 describes a fatigue machine for determining the resistance of metals to repeated stresses, the effects of various factors on the life of metals, and causes of service failures. The Thompson Grinder Company, Springfield, Ohio.

PRECISION THERMOMETERS. 80-page Bulletin "C" describes laboratory thermometers, test thermometers, calorimeter and differential thermometers, certified thermometers, specification thermometers etc., also hydrometers and mercurical barometers. Precision Thermometer and Instrument Co., Philadelphia, Pa.

CONSISTOMETER. A leaflet on the Stephens Mechanical Consistometer which is used in testing and comparing the lubrication qualities of motor oil, aviation oils and transmission lubricants. Consistometer Corporation, 332 S. Michigan Ave., Chicago, Ill.

RECORDING THERMOMETERS. Bulletin No. 169 contains 40 pages completely describing the vapor tension type and gas filled thermometers. It contains valuable engineering information on bulbs, sockets, helical tubes and instrument boards. The Foxboro Company, Foxboro, Mass.

COLORIMETER. A folder describing S.D.C. Colorimeter for determing pH. Rascher & Betzold, 829 Orleans St., Chicago, Ill.

LIQUID FLOW METERS. Bulletin No. 173 is devoted to the theory of flow measurement and the operation, design and construction of the instruments used to measure liquid flow. It contains forty pages of engineering information useful to those responsible for the metering of liquids of all kinds, and is profusely illustrated. The Foxboro Co., Foxboro, Mass.

TESTING MACHINES. A 15 page booklet describing precision hydraulic universal testing machines. Riehle Bros. Testing Machine Co., 1424 North 9th St., Philadelphia, Pa.

EXPERIMENTER. Vol. VI, No. 1 of this publication features the article, "Volume Control in Voice Circuits." General Radio Co., Cambridge A., Mass.

CATALYTIC APPARATUS. Bulletin No. E 13 describes and illustrates apparatus for catalytic hydrogenation. Burgess Parr Company, 111 West Monroe Street, Chicago, Ill.

MELTING POINT APPARATUS. Bulletin No. E 11 describes melting point apparatus designed to provide an easy, rapid, and accurate means for determining the melting points of various materials. Burgess-Parr Company, 111 West Monroe Street, Chicago, Ill.

RESISTORS. Bulletin No. 200 entitled "Measurements of Very High Voltages with Taylor High Voltage Resistors." 12 pages. Photographs and diagrams. Shallcross Mfg. Co., Collingdale, Pa.

MULTIPLIERS & RESISTANCE BOXES. Bulletin 700 describes Kilovoltmeter multipliers for low current meters. Bulletin 900 describes Megohm decade resistance boxes designed for the specific requirements of the physicist, research engineer, and others engaged in scientific investigations. Shallcross Mfg. Co., Collingdale, Pa.

SALINITY-INDICATOR. Instruction No. 23-755 identifies a 16-page booklet describing the salinity-indicator which warns of any change in the saline content of boiler water. Its readings are accurate within plus or minus 25 percent limits of the salinity being tested. Sperry Gyroscope Co. Inc., Brooklyn, N. Y.

CONTROLLERS. Catalogue No. 8008 contains many interesting facts on automatic control applied to various industries; recording controllers; indicating controllers; valve mechanisms and control panels, etc. Brown Instrument Co., 4482 Wayne Avenue, Philadelphia, Pa.

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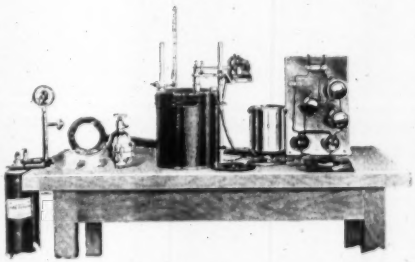

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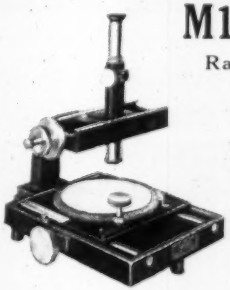

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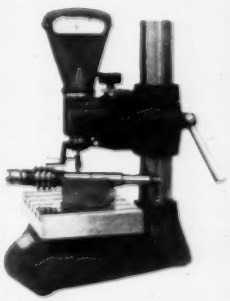

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SPEED AND ACCELERATION. M. F. BEHAR, INSTRUMENTS, Vol. 4, No. 6, August 1931, pages 413-444, 35 figs.

Continuation of Chap. XV. This installment covers:

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MEASUREMENT OF AIR FLOW. E. OWER, INSTRUMENTS, Vol. 4, No. 8, August 1931, pages 445-454, 2 figs.

Chap. VII Anemometers continued. This installment discusses effect of fluctuating and effect of Variation in Wind Speed across the vane circle.

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